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CUMULATIVE EFFECTS OF MICRO-HYDRO DEVELOPMENT ON THE FISHERIES OF THE SWAN RIVER DRAINAGE, MONTANA

I: SUMMARY REPORT

Final Report 1990

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CUMULATIVE EFFECTS OF MICRO-HYDRO DEVELOPMENT ON THE FISHERIES OF THE SWAN RIVER DRAINAGE, MONTANA

I: SUMMARY REPORT

Final

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EXECUTIVE SUMMARY

This two and one-half year study was designed to develop and apply methods to evaluate the cumulative effects of 20 proposed small hydro projects on the fisheries resources of the Swan River drainage - a 1,738 km^2 drainage located in northwestern Montana. The comprehensive resource inventory and subsequent analysis used to predict effects of development are illustrated in Figure A. An aerial survey identified 49 tributary streams that could support fish populations. These streams contained 416 km of habitat and were divided into 102 reaches. Ground surveys of fish populations and stream habitat characteristics were conducted on 74 tributary reaches and in three sections of an 85 kilometer segment of the Swan River.

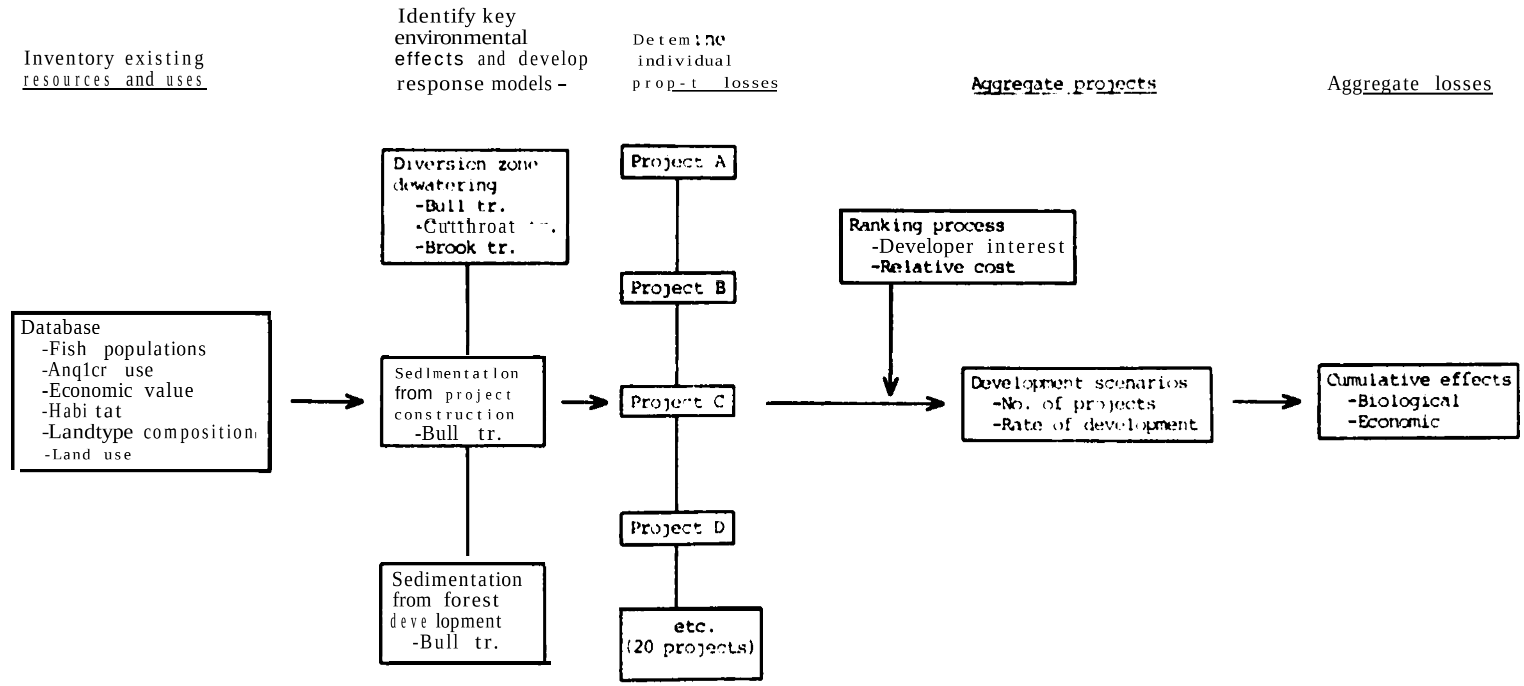
Fish population and reach classification information was used to estimate total populations of 107,000 brook trout, 65,000 cutthroat trout and 31,000 juvenile bull trout within the tributary system. Brook trout were believed to be year-round stream residents and achieved highest population densities in low-gradient reaches. Cutthroat trout were also stream-resident but were found in higher gradient reaches. Bull trout were the only significant migratory species; juvenile populations were greatest in low and moderate gradient reaches. Maximum observed brook trout densities (609 fish275 mm per 300 m of stream) were much larger than peak cutthroat or juvenile bull trout densities (285 and 270 fish per 300 m, respectively).

Streambed substrate score (an integrated measure of streambed porosity) was identified by stepwise multiple regression as the most important stream habitat variable influencing juvenile bull trout densities in tributary reaches. Maximum depth, total instream cover, and drainage area explained most of the variation in cutthroat trout density while instream cover explained most of the variation in brook trout numbers.

Anglers expended approximately 48,000 hours (16,300 angler-days) sport fishing in the Swan River drainage during the 1983-84 fishing season. This total was comprised of 21,700, 16,500 and 9,900 hours in Swan Lake, Swan River, and tributaries, respectively. Kokanee salmon, northern pike, and bull trout were the most numerous species harvested from Swan Lake. Brook, rainbow, and bull trout were the primary species harvested from the river, while brook trout comprised 91% of the tributary harvest. Migratory bull trout up to 800 mm provide a "trophy" fishery in the drainage.

Distribution, abundance, and life history of fish species in the drainage and their contribution to the sport fishery were considered in the cumulative impact analysis. Bull trout were

FIGURE A. CUMULATIVE IMPACT ANALYSIS PROCEDURE.



chosen as the primary species of concern because of their extensive use of project areas, sensitivity to streambed sedimentation, and their importance to the lake and river sport fisheries. Cutthroat and brook trout were lower priority because of their limited contribution to the sport fishery or limited use of project areas.

Dewatering of hydroelectric diversion zones and streambed sedimentation (resulting from forest and small hydro development) were the major impacts considered. The developer proposed to divert up to the entire streamflow during low flow months because maintenance of recommended minimum bypass flows would not allow profitable project operation. Dewatering was assumed to result in a total loss of fish production in these areas.

A landtype-based watershed model was used to estimate future sediment loads, both natural and man-induced, in study area streams. Effects of increased sediment on fish habitat were predicted using an observed negative relationship ($r=-0.75$) between substrate quality (measured as “substrate score”) and computed increases in sediment delivery over natural levels due to road construction. Stream gradient was an important determinant variable in this relationship but sediment directly associated with logging activities was not significant. Sediment expected from micro-hydro development was estimated by considering ground disturbance which would result from construction of access roads, penstocks, and transmission lines described in preliminary study permits for the projects.

Since juvenile bull trout densities were correlated with stream substrate scores ($r=0.63$), projected changes in substrate scores were used to predict the effect of development on bull trout production. Predicted effects were expressed as a percentage of potential bull trout production lost. The effect of increased sediment on resident cutthroat and brook trout was not modeled because densities of these species were not positively correlated with substrate scores.

Due to diversion zone dewatering and streambed sedimentation, small hydro projects would cause the loss of 2% to 72% of juvenile bull trout populations within individual project drainages. Considering the additional effect of forest roads, total losses range from 11% to 84% of potential bull trout production in individual streams, or 1% to 8% of the drainage-wide migratory bull trout production. Small hydro development would also result in losses of up to 90% of resident cutthroat trout and 50% of resident brook trout in project streams. These losses constitute up to 5% of the cutthroat trout and 2% of the brook trout populations in the Swan tributary system.

The effects of individual projects were aggregated to predict the cumulative impact of multiple small hydro developments (Figure A). Because no projects were constructed during the study period, six hypothetical strategies of development were simulated.

These ranged from four projects built over four years (one each year) to all 20 projects built in one year. Projects were ranked according to developer interest and cost factors to determine a logical sequence of construction for these six scenarios.

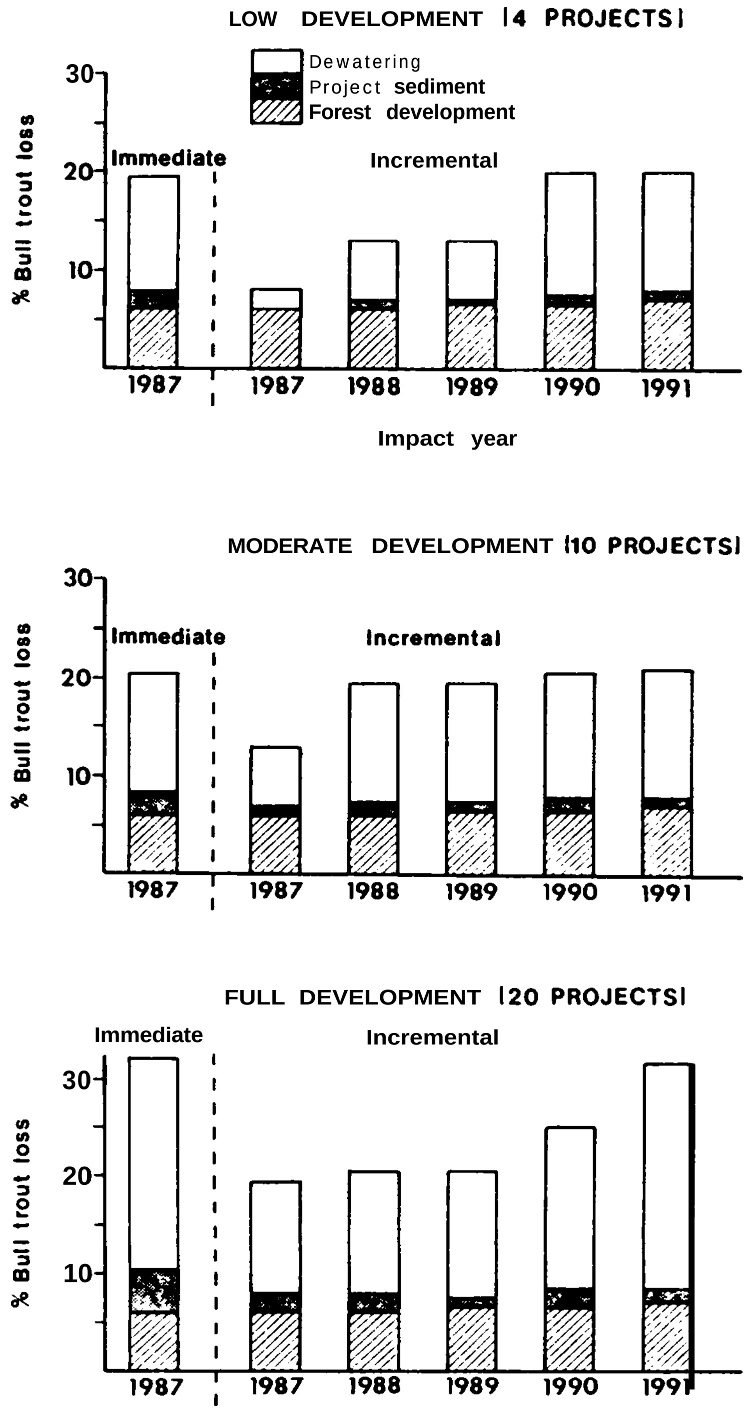
Multiple project development with subsequent dewatering of diversion zones would have a significant cumulative impact on the migratory bull trout fishery of the Swan drainage. Even a low level of development (only four projects) would eventually result in the loss of about 13% of potential juvenile bull trout production, with an additional 7% lost due to forest roads (Figure B). The cumulative loss (20%) is substantial because three of the four highest ranked projects involve bull trout rearing streams. A moderate level of development (10 projects) would ultimately cause a 14% loss of bull trout, while full development (all 20 projects) would reduce juvenile bull trout populations by 24%. Cumulative losses increase to 21% for moderate development and 31% for fulldevelopmentwhen additional sedimentation from forest roads is considered. As shown in Figure B, dewatering of diversion zones accounted for the greatest bull trout losses.

The cutthroat trout fishery in Swan River tributaries would also be significantly affected by stream dewatering associated with multiple project development. Cumulative losses of 7%,12%, and 18% were predicted for low, moderate, and full development levels, respectivelv. Brook trout were less abundant than cutthroat in proposed project areas. As a result, estimated dewatering impacts on this species were small, ranging from 2% of the tributary population lost with a low level of micro-hydro development to 4% lost with full development.

Using the travel-cost technique, the net economic value of the Swan sport fishery to anglers was estimated to be $788,000 per year. This sum was comprised of $455,000, $265,000, and $68,000 annually for the Swan River, Swan Lake, and tributary fisheries, respectively. Since this technique could not be used to estimate the value of partial fish losses, three contingent-valuation approaches and the hedonic travel-cost method were employed. The annual value to anglers of a hypothetical 25% fish loss from the drainage based on contingent valuation questionnaire responses ranged from $250,000 (based on willingness-to-drive) to $2.6 million annually (based on willingness-to-sell). Using willingness-to-pay, the value was $331,000 per year.

Results of hedonic travel-cost analysis indicated that bull trout were substantially more valuable to anglers than were "trout" in general. Anglers were willing to pay an estimated $450 per party-visit to fish specifically for bull trout as compared to $30 to fish for "trout". Using these data, the annual net value of the bull trout fishery in Swan Lake and the Swan River was estimated to be $232,000. This was substantially higher than the $87,000 estimated for the "trout" fishery, which received about six times as much fishing pressure.

FIGURE B. PREDICTED LOSSES OF MIGRATORY BULL TROUT PRODUCTION DUE TO SMALL HYDRO DEVELOPMENT IN THE SWAN RIVER DRAINAGE.



Our study demonstrated that:

1. Development activities have on-site impacts as well as direct and indirect impacts on downstream areas that can be expressed in biological and economic terms.

2. The impact of small hydro development can vary widely between fish species and between projects.

3. The timing and extent of other land development activities (road building, logging, mining, grazing, etc.) within a river drainage must be considered to properly evaluate cumulative effects.

4. In the Swan drainage, dewatering of stream habitat by hydroelectric diversions would have a more serious and permanent effect on fisheries than would sediment from construction activities. However, stream sedimentation may be of much greater concern in regions where soils are more unstable.

5. Different sport fish species have different values to anglers. The values are not necessarily proportional to levels of angler use.

These findings provide useful preliminary management tools, but verification of the predictive models should be pursued with monitoring programs. Also, the factors considered in this study (i.e. dewatering and sediment production) may have different importance elsewhere. Other project-related effects, such as water temperature alterations, gas supersaturation, upstream passage, downstream passage, and turbine mortality should be considered whenever this type of development is proposed.

ACKNOWLEDGEMENTS

The successful completion of this project required the collective efforts of a great many people. Pat Graham was largely responsible for the initiation of the project and provided guidance and direction throughout the study period. Steve Bartelt, Lani Morris, and Pat Clancey served as field crew leaders and their efforts are deeply appreciated. Bob Braund and John Wachsmuth were fieldworkers fortwoor more seasons and Janice Pisano and Vicki Rosen collected creel census and economic information. Chuck Weichler, Steve Glutting, Jeff Holland, and Bill Swaney also served as fieldworkers. Chuck Weichler constructed a data entry form and wrote a computer program to enter and summarize stream habitat transect data. Bob McFarland, Laney Hanzel, Dal Burkhalter, and Carol Bittinger also provided valuable assistance in computer analysis. Fred Nelson supervised the computer analysis of instream flow (WETP) data. In addition to being a good neighbor, Bob Zielinske assisted in fish trap maintenance on Goat Creek. Jeff Jordan of Hydro Management Inc. provided access to the Whitefish small hydro project. Janice Pisano and Jean Blair typed the completion documents. Special thanks go to the MDFWP biologists and fieldworkers who gathered information from six other lakes and rivers in the state to facilitate the economic analysis. The assistance of Dave Whitesitt in gathering logging and roading data from Plum Creek Timber Company was appreciated. Phyllis Snow, Al Martinson, and Jim Dry of the Flathead National Forest made important contributions to the sediment modeling effort. Pat Gilmore, also of the Flathead Forest, developed the computer program needed to apply the sediment model. And finally, the authors wish to thank all reviewers for their valuable comments.

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INTRODUCTION

Interest in developing small scale hydropower generating facilities in the Pacific Northwest has increased dramatically following the passage of the Public Utilities Regulatory Policy Act (PURPA) by Congress in 1978. Section 210 of PURPA provided strong incentives to prospective small hydro developers by mandating that 1) utilities must purchase power generated by any independent producers who are willing to sell, and 2) the utilities must pay a favorable price (known as the "full avoided cost") for this electricity. Full avoided cost is commonly known as the amount the utility would have to pay to generate or acquire "new" electricity at present day costs. Tax incentives were also provided to prospective developers through state and federal legislation such as the National Energy Security Act of 1980.

Prospective small hydro developers responded to the various development incentives by submitting thousands of applications for preliminary permits for small hydro projects to the Federal Energy Regulatory Commission (FERC) during 1981 and 1982. Preliminary FERC permits serve to establish priority development rights for a hydropower site for an 18-month to three year period. This time-span is used by the developer to conduct the detailed feasibility and design studies needed to file for a license (or licensing exemption) to develop the site.

The "hydro-rush" became readily apparent in Montana during 1981 and 1982 when developers filed applications for preliminary permits for nearly 90 hydropower sites. Many of these filings were for sites in northwestern Montana and 20 preliminary permits were issued for sites on tributary streams in the Swan River drainage. Much of this interest proved to be speculative since at the time of this writing most of the preliminary permits for sites in northwest Montana have expired or were surrendered and only one commercial project has actually been constructed (the municipal water supply project in Whitefish, Montana).

The prospect of the development of a large number of small hydro projects in a river basin such as the Swan raised serious questions concerning the issue of cumulative impacts. While no single project may have an unacceptable impact on resident or migratory fish populations within a river basin, the combined incremental effects of a number of projects could prove to be significant. Each individual project could affect fish populations on-site as well as in downstream areas. These impacts include stream dewatering and flow fluctuation within diversion areas, streambed siltation resulting from construction activities and potential penstock ruptures, turbine-related fish mortality, gas supersaturation, and the creation of barriers to upstream fish migration.

The Northwest Power Planning Council (1982) recognized the potentially harmful cumulative effects of small hydro development (less than 5 megawatts) on fish and wildlife resources within individual river basins. In accordance, the Council recommended Measures 1204 (b) (1) and (2) toinsurethatpotentialcumulative effects of existing and proposed multiple hydroelectric developments within a single river drainage are addressed by federal project operators and regulators, and to encourage development of criteria and methods for assessing cumulative fisheries impacts of multiple hydroelectric developments.

This study addresses portions of Measure 1204 (b) (2) in the Columbia River Basin Fish and Wildlife Program. The purpose of the study is to design, develop and apply methods to determine the potential cumulative effects on both migratory and non-migratory trout populations of the Swan River drainage that could result from extensivesmall-scale or "micro-hydro" development (less than 5 megawatts). These impacts will be expressed in both biological and economic terms.

Very little published information exists that describes the environmental effects of high-head small hydro development. While a substantial amount of information regarding fish mortality associated with passage through turbines of large hydropower projects is available, little such information exists for the types of turbines typically installed in small low-head hydropower projects (Gloss and Wahl 1983). Even less information exists for the types of turbines (impulse turbines such as the Pelton Wheel) typically installed in small-scale high-head projects (Turbak et al. 1981). This paucity of information is in large part due to the fact that widespread interest in developing such projects is a recent phenomenon. Hence, few if any on-site studies have been conducted.

To our knowledge, there are no completed studies that concern the cumulative impacts of hydropower development on fisheries resources in any area of the Pacific Northwest. As per Measure 1204 (b) (2) of the Columbia River Basin Fish and Wildlife Program, the Northwest Power Planning Council is in the process of initiating a study to determine cumulative impacts of hydroelectric development on the fish and wildlife resources of the Columbia River Basin. Also, FERC (1985) recently released a draft document that describes a proposed procedure to evaluate the cumulative effects of small hydro development in each of three river basins in the northwestern United States.

The present study was divided into two phases. The first phase involved the collection of a drainage-wide data base consisting of fish population, stream habitat, and land use information. This was used to develop cumulative impact models and criteria for evaluating potential fisheries impacts of proposed micro-hydro developments. Methods used for determining fish population size, instream flow needs, and stream habitat quality were described and evaluated during this phase of the study and were reported by Leathe and Graham (1983). The second study phase involved the collection of economic and angler use data to enable the results of the biological assessment to be expressed in economic terms. A third study phase was also recommended to monitor the effects of construction and operation of one or more small hydro projects to verify study predictions.

As might be expected, the successful achievement of the study goals involved a substantial amount of coordination and cooperation among various state, federal, and private entities. The Montana Department of Fish, Wildlife and Parks (MDFWP) initiated the study and was responsible for collecting virtually all "on-the-ground" information. These data include a large body of information concerning fish species abundance and distribution; fish life history: fish habitat in tributary streams; hydrology and instream flows; and fishing pressure and harvest on Swan Lake, Swan River, and its tributaries. The U.S. Forest Service (USFS) compiled information concerning past and projected future timber harvest activities on state, federal, and private lands in the drainage and explored the relationshipbetweenland use (primarily logging and associated road construction and maintenance) and levels of fine material in streambeds. This information was used to predict the amount of streambed siltation that could result from logging and micro-hydro development activities. ECO Northwest, a private consulting firm, designed the economic portion of the study and analyzed the economic data collected by MDFWP in conjunction with the creel survey (ECO Northwest 1984).

This report summarizes the major findings of this two and one-half year study. More detailed information regarding the findings of fisheries, angler use, and hydrologic investigations involved in this study may be found in Leathe et al. (1985a). Maps of surveyed tributary streams and narrative descriptions of habitat features and fish populations were compiled by Leathe et al. (1985b). Also, a final report that details the findings of the economic investigations and describes and evaluates applicable methods for determining the value of fish population losses was issued by EC0 Northwest (1984).

DESCRIPTION OF STUDY AREA

The Swan River is located in northwestern Montana, west of the Continental Divide (Figure 1). The river flows north from its headwaters in the Mission and Swan mountains and enters Flathead Lake at the town of Bigfork, Montana which is 23 river kilometers (14 miles) downstream from Swan lake. Several peaks in the Mission (to the west) and Swan (to the east) mountain ranges exceed 2,743 meters (9,000 feet). The Flathead River drains Flathead Lake and flows into the Clark Fork River, which eventually leaves Montana and enters the Pend Oreille River system in northern Idaho.

The Swan River has a drainage area of 1,738 km^2 (671 sq. mi.), measuredatthe outlet of Swan Lake, and flows through a heavily forested glaciated valley that is relatively flat and five to ten kilometers wide. The average drop for the 83 km (52 mile) river section between Lindbergh and Swan lakes is 4.5 meters per kilometer which is equivalent to a 0.4% gradient. Lateral channel movement and subsequent bank erosion in this river section have resulted in the presence of excessive amounts of channel debris and numerous log jams which limit recreational floating use.

Mean annual flow of the Swan River is 165 cubic feet per second (cfs) at a gauging point 6.4 km downstream from Lindbergh Lake near Condonand about1300 cfs immediately downstream from Swan Lake (United States Geological Survey 1981). Peak discharges typically occur in June (Figure 2) and are determined by the amount and rate of snowmelt in this mountainous watershed. Streamflows in the largest tributaries (Woodward, Elk, Glacier, and Lion creeks) ranged between 19 and 69 cfs during September of 1982. Peak spring flows in the river and tributaries are usually 15 to 30 times larger than low flows measured in the fall.

The Swan River meanders for about20 kilometers below Swan Lake before entering a high gradient canyon section immediately upstream from Flathead Lake. The high gradient section is very popular among whitewater floating enthusiasts and is also the site of a 4.1 mega watt hydroelectric facility constructed in 1902 and currently operated by the Pacific Power and Light Company. A fish ladder was constructed to enable migratory westslope cutthroat trout, bull trout and kokanee salmon from Flathead Lake to pass over the 12-foot high concrete diversion dam and access the Swan River drainage. However, this ladder did not become operative to migrating trout until 1959 (Domrose 1974). Historical use of the passage facility has been limited (Graham et al. 1981a), probably because of design flaws and the length of time required to render the ladder operative. Consequently, the fisheries within the Swan drainage can be considered isolated from the remainder of the Flatheaddrainage.

Numerous high mountain lakes, valley lakes, and potholes are scattered throughout the Swan River drainage (Figure 1). Swan Lake is the largest and has a surface area of 1,085 hectares (2680

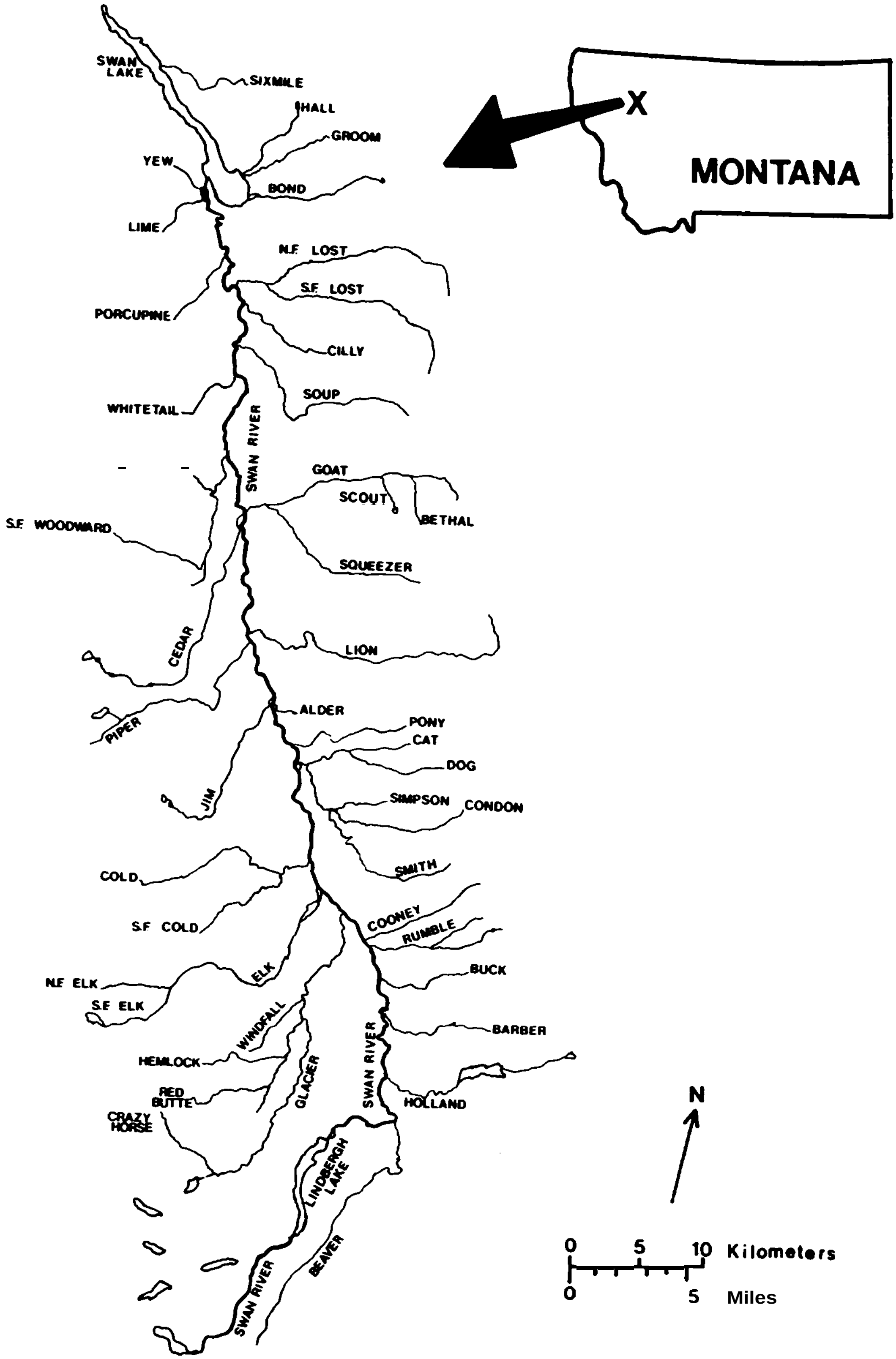

Figure 1. Map of the Swan River drainage, Montana.

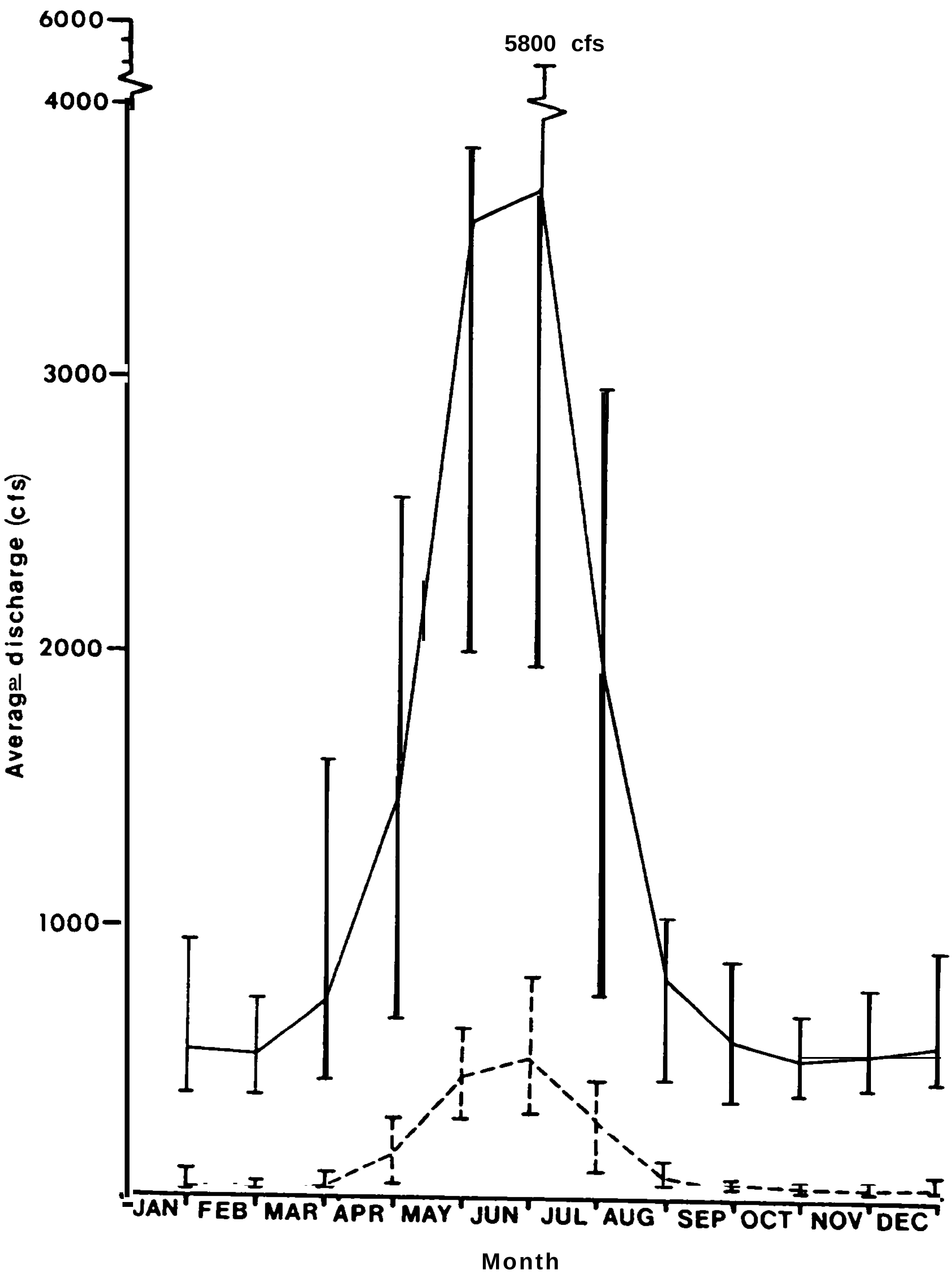

Figure 2. Average and ranges of mean monthly flows in the Swan River immediately below Swan Lake (solid line) and near Condon (broken line) for the years 1972 through 1982.

acres). Lindbergh Lake (294 hectares or 726 acres) and Holland Lake (165 hectares or 408 acres) are the two other major lakes and are located in the upper portion of the drainage. The fisheries of these two subdrainages are assumed to be independent from the remainder of the Swan drainage. Since there were no proposed micro-hydro sites in these drainages, they will not be considered in the cumulative fisheries impact assessment.

Land ownership patterns in the Swan Valley are mixed and vary widely between tributary drainages. North of Soup Creek, most of the land is Flathead National Forest with various private parcels occupying the valley bottom. South of Soup Creek, the valley is characterized by a checkerboard pattern of National Forest (200,000 acres), Swan River State Forest (39,000 acres), and Plum Creek Timber Company lands (87,000 acres). Further south at Fatty Creek, state land drops out of the checkerboard. Smaller private holdings (23,000 acres total) occupy much of the valley floor.

Seven of the proposed micro-hydro streams lie in drainages entirely or almost entirely on National Forest System lands. Soup Creek drains predominately Swan River State Forest lands, while most of Cold Creek's basin is owned by Plum Creek Timber Company. The headwaters of Cedar, Piper, Jim, Cold, Elk, and Glacier creeks originate in the Mission Mountains Wilderness.

Development consists primarily of road construction and timber harvest in Swan tributary basins. Limited livestock grazing also occurs in scattered lower-elevation locations. Logging intensity varies from heavily-cut drainages like Cold Creek, where over 10% of the basin has been clearcut in the last seven years, to unharvested (and unroaded) areas like upper Elk and Lion creek drainages. Road densities typically reflect the extent of timber harvest. In Swan tributaries, roads occupy from 0.1 to 2.8% of drainage basin area.

All proposed micro-hydro facilities in the Swan River drainage were high head projects located on mountain streams (Figure 3) and had installed capacities ranging between 100 kilowatts and 1.5 megawatts (Table 1). Water would be diverted into 12 to 20 inch diameter penstocks by the construction of three-foot high diversion dams in the stream. The diverted water would be transported thousands of feet downstream in penstocks and released through high-pressure jets which would drive an impulse turbine (Pelton wheel) to generate electricity at the powerhouse before being returned to the stream. Stream gradients within the proposed diversion zones ranged between 3% and 21%. Gross head (vertical drop) of the proposed projects ranged between 90 and 527 m and averaged 227 m (744 feet).

During the study period the principal gamefish species found in the tributaries to the Swan River were non-native brook trout (*Salvelinus* fontinalis) as well as native westslope cutthroat trout (*Salmo clarki lewisi*) and bull trout (*Salvelinus confluentus*). In

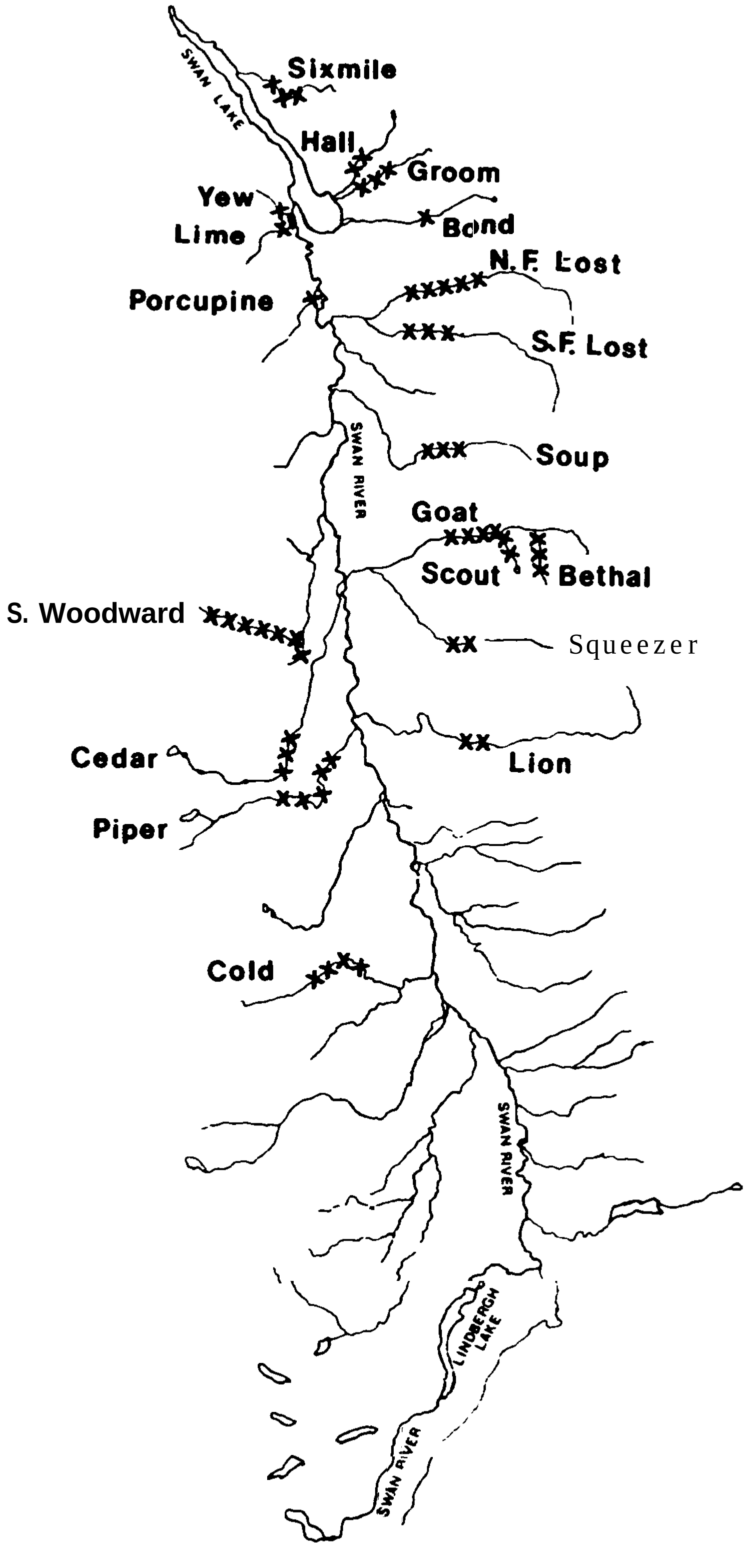

Figure 3. Map of the Swan River drainage, Montana depicting proposed locations of 20 micro-hydro sites.

Table 1. Information pertaining to proposed micro-hydroelectric facilities in the Swan River drainage, Montana.

Project No.	Project name	Penstock length (ft)	Average channel gradient (%) within proposed diversion area	Penstock diameter (in)	Installed capacity (kw)	Estimated late summer flow (cfs)[a]
5093	Yew Cr.	4,200	9.6	12	100	1.1
5095	Bond Cr.	3,700	15.5	20	300	6.0
5097	Lime Cr.	3,400	15.8	12	100	0.5
5098	Hall cr.	5,100	15.2	16	400	2.9
5105	Sixmile Cr.	3,900	3.3	16	150	2.1
5517	Scout Cr.	5,000	21.9	--	407	2.7
5518	Goat Cr.	12,200	4.8	--	430	6.4
5519	S.F. Lost Cr.	11,800	3.0	--	291	14.4
5520	Soup Cr.	8,200	11.5	--	377	8.5
5521	Porcupine Cr.	4,800	8.7	14	259	2.2
5522	Bethal Cr.	9,200	8.5	12	263	3.8
5523	N.F. Lost Cr.	13,250	4.3	12	184	6.4
5524	Piper Cr.	17,000	6.9	14	624	11.0
5525	Cedar Cr.	11,500	10.8	12	377	4.2
5556	S. Woodward Cr.	18,000	11.4	16	1411	9.6
5557	Squeezer Cr.	7,000	10.3	16	604	6.3
5558	Cold Cr.	16,000	6.0	16	929	24:0
5559	Lion Cr.	5,000	5.6	16	352	18.0
5733	Groom Cr.	7,600	11.7	14	376	2.1
5783	Trib to S. Woodward	2,750	11.2	16	2-100	8.5

[a] Flow estimated at powerhouse.

the Swan River upstream from Swan Lake, non-native brook trout and rainbow trout (Salmo gairdneri) were the predominant gamefish species with fewer numbers of bull trout and westslope cutthroat trout present. The predominant gamefish species in Swan lake were non-native kokanee salmon (Oncorhynchus nerka) and northern pike (Esox lucius) as well as native bull trout. Rainbow trout, cutthroat trout, and brook trout were also present in Swan Lake.

Bull trout are the most noteworthy migratory species in the drainage. During the summer, adult fish (400 mm to more than 800 mm total length) migrate from Swan Lake to specific tributary streams where they spawn in the fall prior to returning to the lake. After emerging from the gravel in April, young bull trout spend from one to three years in the stream before migrating to the lake where maturity is attained at age five or six.

The species composition and life history traits of the fish community of the Swan drainage have been dramatically altered from virgin conditions by man's activities. Probably the most adversely affected species has been the westslope cutthroat trout, which was likely a dominant species at one time that migrated between lake, river, and tributaries for spawning and rearing purposes as it still does in the Flathead bake/River system. The introduction of exotic fish species in all portions of the Swan drainage (resulting in increased competition, predation, and hybridization), possible habitat deterioration from land use activities, and differential vulnerability to angling have likely been responsible for the reduction of cutthroat trout abundance. Exotic fish species now comprise a major portion of or even dominate the fish communities in various portions of the drainage. Examples include brook trout in lower gradient tributary reaches, brook and rainbow trout in the Swan River, and kokanee salmon and northern pike in Swan Lake.

At the present time, genetically pure native westslope cutthroat trout populations in the Swan drainage probably only occur in the upper reaches of a few headwater tributaries. The westslope cutthroat trout is currently listed as a fish species of "special concern" in Montana because of its limited distribution in the state, plus the fact that it has been extirpated from a large portion of its native range in the interior regions of the United States (Holton 1980; Behnke 1979). Bull troutweredesignated a species of special concern in Montana in early 1985.

Aerial Survey

Standard USGS topographic aerial survey maps (1:24,000 scale) were used to determine stream order, potential reach breaks, and reach drainage areas in tributaries to the Swan River at or above Swan Lake. Tributary streams were delineated into one-kilometer sections (beginning at their mouths) on topographic maps to facilitate the location of important stream features and ground survey sites.

Aerial pre-surveys were conducted for all streams in the drainage using a helicopter technique similar to that developed in British Columbia (Chamberlin 1981) and which has been used in other parts of the Flathead River Basin (Fraley and Graham 1981). Each survey was initiated at the downstream end of the tributary. A trained observer narrated key habitat characteristics, locations of stream features, and the locations of potential reach breaks into a tape recorder while the helicopter proceeded upstream. Reaches were defined as being stream sections having "a repetitious sequence of physical processes and habitat types" (Chamberlin 1981). Thus, changes in channel gradient and stream habitat uniformity were important factors considered in defining reach boundaries.

Each aerial stream survey was terminated when streamflow and channel gradient thresholds (<0.5 cfs and/or >25% gradient) deemed necessary to support resident trout were exceeded. It is likely that the kilometers of potential trout habitat was overestimated using the minimum flow criterion since aerial surveys were conducted during mid-September. Available hydrologic information indicates that these creeks were at base flow during this time but absolute minimum flows occur during the winter months. Streamflow data gathered from five tributaries during this study indicated that average monthly winter flows averaged 18% lower than average flows during September.

Final reach boundaries, significant habitat features (log jams, waterfalls, slumping banks, etc.), and recommended ground survey sections were located as the helicopter proceeded downstream to the mouth of the stream. Approximately 25 kilometers of stream length were surveyed per hour using this technique involving both up and downstream passes. Tape recorded information was later transcribed onto office forms.

Reach Selection

Available time and manpower did not allow ground surveys to be conducted on all of the 102 stream reaches identified by the aerial survey as having potential fisheries importance. Consequently, a sampling scheme was devised to obtain a representative subsample of all reaches in the drainage. To insure that overall study objectives were met, top priority was placed on obtaining ground survey information for stream reaches situated within or downstream from proposed small hydro project areas. This entailed ground surveys on 25 reaches directly involved in proposed hydro diversions as well as on 12 reaches located downstream from proposed hydro projects.

The remainder of the 74 total reaches thatwereground surveyed during the study were randomly selected from a pool of all reaches stratified into gradient/drainage area categories (Table 2). Each gradient-size category was sampled in proportion to its relative abundance throughout the drainage. Reaches sampled in the course of hydro site analysis were considered to be randomly selected within gradient-size categories. They were included in the fisheries database because only cursory fisheries information was considered by the hydro developers in their site identification process. Studies completed in other portions of the Flathead drainage and elsewhere have documented the importance of stream gradient and size in determining salmonid species abundance and distribution in mountainous watersheds (FraleyandGraham1981, Graham et al. l981b, Griffith 1972, Hartman and Gill 1968, Platts 1979).

Ground Survey

Stream habitat surveys were conducted by crews of two technicians on one or two kilometer-long representativesections of selected reaches. A number of habitat variables including feature (pool, riffle, run, pocket water, cascade), flow character, debris presence and stability, and channel splitting were measured at each of 40 sampling stations selected by random pacing. Intensive measurements of other habitat variables were made at 15 of the 40 randomly selected stations using a line transect method similar to that described by Herrington and Dunham (1967) and modified by Shepard and Graham (1983a). Measured variables included water depth, dominant and subdominant substrate types, instream and overhead trout cover, wetted width, channel width, substrate embeddedness, substrate composition, and D-90. Field manuals describing habitat terminology and measurement techniques were carried by each field crew. Channel stability was evaluated for each reach using a procedure employed by the Northern Region of the U.S. Forest Service (USDA, Forest Service 1975). Streamflow was measured at one point within the survey section using either a Gurley Type AA or a pygmycurrentmeter. Atypical habitat survey for one reach required one day of field effort for a crew of two technicians. An analysis of the replicability of habitat measurements is included in Leathe et al. (1985a).

Table 2. Channel gradient (percent) and drainage area (square kilometers) classification scheme used to select reaches for ground survey in the Swan River drainage.

Gradient (%)	Drainage area [a/] (km^2)	Total in drainage: No. reaches	Total in drainage: Stream km	Amount sampled: No. reaches	Amount sampled: Stream km
		5			
0-3%	0-20	14	14.5	3	8.4
	>20-50		50.5	13	47.5
	>50	15	92.2	11	66.3
>3-6%	0-20	12	46.6	8	32.3
	>20-50	12	55.6	9	44.1
	>50	2	13.8	1	9.5
>6-13%	0-20	22	66.8	14	40.5
	>20-50	6	33.6	5	29.6
	>50	1	1.5	1	1.5
>13%	0-20	13	40.5	9	25.8
	>20-50	--	--	-	--
	>50	--	--	--	--
Total		102	415.6	74	305.5

a/ Drainage area is defined as the total land area drained by a reach. This includes all lands drained by upstream reaches (if any).

Data Analysis

The relationships between fish population density and measures of habitat quality in tributary reaches were explored to identify key habitat variables that influenced fish abundance and distribution. Once these variables were identified, predictions regarding how they would be affected (if at all) by proposed small hydro development would be made and then translated into effects on fish populations.

Seventy-six stream habitat variables were considered for possible inclusion in statistical models design& to describe the relationship between habitat characteristics and population densities of cutthroat, bull, and brook trout (Appendix A-l). Separate models were developed for each species because their distribution, abundance and habitat preferences within Swan tributaries appeared to be different. Species models were constructed usingdataonly from reaches that contained the species in question since factors other than habitat guality (such as the presence of migration barriers, periodic dewatering, competing fish species, unsuitable water temperatures, or heavy fishing pressure) may have been responsible for the absence of the species in other reaches.

A substantial amount of intercorrelation was &served among the 76 measured habitat variables considered in each species model because of the natural interdependence that exists between factors that interact to create fish habitat. To counteract this problem, correlation matrices were generated to display simple correlations between all variables in each data set. For each data set, habitat variables were progressively eliminated until a final group was obtained that exhibited a relatively small amount of intercorrelation, i.e. simple correlation coefficients (r-values) between independent variable were less than 0.6O. As a result, only 18 of the 76 original variables were selected (Appendix A-l) and only 11 or 12 of these were considered in each model.

Habitat transect data were summarized on the Discovery microcomputer system in the MDFWP Kalispell office. Preliminary analysis of habitat and fish population data was conducted on the same micro-computer system using statistical procedures described by Lund (1983). Summarized habitat and fish population data were also entered into the Honeywell CP-6 mainframe computer at Montana State University for more detailed analysis using SPSS (Statistical Package for Social Scientists; Hull and Nie 1981). To facilitate data access by other resource management agencies, detailed stream reach and fish population information was entered into the Montana Interagency Stream Fishery Data Storage System described by Holtcn et al. (1981).

FISH POPULATIONS AND BIOLOGY

Fish Population Size

Tributaries

Fish population estimates were made in a representative segment within the habitat survey section of each reach selected for ground survey. Populations of fish 75 mm and longer (total length) in most reaches were made using either a two-sample removal method or mark-recapture technique. Population estimates were calculated using equations from Seber (1973) as detailed in Leathe and Graham (1983).

Removal estimates were made in stream sections that were 100 to150 meters long and blocked on the downstream end with either quarter-inch mesh nylon netting or hardware cloth. Upstream ends were blocked by either a natural feature or with another block net. Each removal sample consisted of an intensive downstream pass through the blocknetted section using electrofishing gear. Most electrofishing was conducted by a crew of two technicians (one shocker, one netter) using a Coffelt BP-1C gas-powered backpack electrofishing unit. Accessible large (i.e. more than 15 cfs) streams were electrofished using bank electrofishing gear consisting of a llO-volt Homelite generator and a Coffelt VVP-2C variable voltage pulsator. Fish collected during each pass were held until electrofishing was completed.

When statistical criteria described by Leathe and Graham (1983) for two-sample population estimates were not met, either a third electrofishing pass was made in order to derive a three-sample removal estimate (Seber 1973), or the fish were marked and redistributed for a mark-recapture estimate. Efforts were made to avoid the use of the three-sample technique because comparisons made during 1982 (Leathe and Graham 1983) indicated that three-sample estimates were less satisfactory than those derived using either the two-sample or mark-recapture techniques. The two-sample method was preferred on small streams (i.e. less than 25 cfs) because it was sufficientlyaccurateand could be completed by a crew of two persons in a single day.

Mark-recapture population estimates were obtained for several large streams (in excess of 25 to 30 cfs) and in fish population monitoring sections located in and around proposed hydro project areas. Electrofishing runs were made in 300 to 350 m sections that were blocked at their downstream ends. Marked fish were distributed by hand throughout the section and allowed to redistribute for at least three full days prior to the recapture run(s). Guidelines presented in Shepard and Graham (1983b) as derived from Jensen (1981) were used to insure that the 95% confidence interval for the estimate of the dominant species in a section was no more than plus or minus 25%. Statistical formulae for estimating population size and variance were from Seber (1973) and were described by Leathe and Graham (1983).

Swan River

Attempts were made to obtain mark-recapture electrofishing estimates oftroutpopulations in three sections of the Swan River between Swan and Lindbergh lakes during the fall of 1982. The specific sample site locations and techniques employed were described by Leathe and Graham (1983).

Swan Lake

The distribution and relative abundance of fish species in Swan Lake was investigated in mid-April of 1983 using shoreline sets of standard experimental gill nets having dimensions of l.83 m x 38.1 m and consisting of equal-length panels of 19, 25, 32, 38 and 51 millimeter mesh (bar measure). Overnight gill net sets were made at two sites (east shore, west shore) within each of three major lake areas (north end, middle area, south end). At each netting site, a floating set consisting of two nets tied end to end was made perpendicular to and tied off at the shoreline. A bottom set of two sinking gill nets tied end to end was also made at each site, perpendicular to the shoreline. Floating nets were set over waters up to 18 m (60 feet) deep and sinking nets were set in waters that were 2-26 m (6-85 feet) deep. The gill netting program was designed to duplicate surveys on Flathead Lake (Leathe and Graham 1982) and Hungry Horse Reservoir (May and McMullin 1984).

Fish Movement

A variety of techniques were used to determine fish movement patterns within the drainage. Each method involved the tagging of fish and reliance upon tag returns from anglers or from MDFWP sampling in other parts of the drainage. Irrespective of species or collection method, large fish (>225 mm total length) were tagged with numbered Floy FD-68BC anchor tags whereas small fish (100 to 225 mm) were tagged with numbered Floy FTF-69 fingerling tags sewn through the fishes, body at the base of the first anterior ray of the dorsal fin.

Standard box traps (Montana Department of Fish and Game 1979) with one-half inch hardware cloth leads were installed during the spring of 1983 in the lower reaches of five tributary streams to determine the status of migratory westslope cutthroat in the drainage. These streams were selected because substantial population densities of cutthroat trout were found in electrofishing surveys during the previous summer; the streams were in close proximity to Swan Lake, which periodically received hatchery plants of westslope cutthroat; and the streams appeared to have adequate spawning habitat. Upstream as well as downstream traps were placed in each stream prior to spring runoff and were operated until mid-July to monitor possible smolt emigration as well as the influx of spring spawning adults. Specific locations of trap sites are presented in Leathe et al. (1985b).

Movements of adult bull trout from Goat and Cold creeks were monitored by tagging adult fish that were captured in box traps or fyke nets (with hardware cloth leads) as the fish moved out of the spawning tributaries. The traps or nets were installed near the mouth of the streams in early September after nearly all of the adult bull trout had entered thetributarysystems and spawning had commenced. This operating strategy minimized handling of the fish and prevented disruption of upstream spawning runs. The Cold Creek trap was operated only in 1983 whereas the Goat Creek trap was operated in both 1983 and 1984.

A series of 14 electrofishing sections was established in April 1983 in each of two 2 km study areas of Soup Creek to evaluate seasonal instream movements of cutthroat trout (upper study area) and brook trout (lower study area). Each of the 14 electrofishing sections within each study area was approximately 30 m long and the sections were spaced about 110 m apart. All sections in the upper study area were re-electrofished in the fall of 1983 and again in the spring of 1984. The lower study area was revisited only in the fall of 1983 when eight of the14 original sections were surveyed before ice conditions prevented further work. Upstream and downstream fish traps were installed below each study area during the spring of 1983 to monitor potential emigration of tagged fish.

In addition to the above efforts, a large number of trout were tagged in the Swan River and its tributaries during the course of fish population inventory and monitoring work. This work involved electrofishing on more than 70 sections of tributary streams as well as three river sections.

Age and Growth

Total body length of fish collected during the study was measured to the nearest millimeter. Scales were taken from an area just above the lateral line along an imaginary line drawn between the posterior insertion of the dorsal fin and the anterior insertion of the anal fin. Cellulose acetate impressions of scales were examined at 71X magnification using a microfiche reader. Distances from the focus to annuli were measured to the nearest millimeter and recorded directly onto computer coding sheets.

Age and growth information was analyzed on the Discovery computer system in the Kalispelloffice of MDFWP using programs devised by Department personnel. Back-calculated lengths of fish were derived using log-log regression equations describing body length: scale radius relationships.

Spawning Surveys

Drainage-wide bull trout spawning site censuses were conducted during October and November of 1982,1983, and 1984. Time series surveys and fish trapping in the Goat Creek drainage, an important bull trout spawning drainage, indicated that most spawning was completed by the end of September.

During the first field season, potential bull trout spawning habitat was identified using aerial reach survey information. Graham et al. (1981b) reported that most bull trout spawning in the upper Flathead River drainage occurred in large high-order stream reaches having low gradients (usually less than three percent) and relatively high percentages of preferred gravel and cobble spawning substrate. The list of survey sections was refined asthestudy progressed and more information regarding bull trout spawning use and distribution of juvenile bull trout became available. No evidence of main stem spawning in the Swan River was found.

Bull trout redds were for the most part easily recognized by trained survey personnel since these large fish (usually a minimum of 400 mm total length at maturity) spawn during thelowflowperiod when water clarity is excellent. Spawning activity results in the formation of a depression or pitatthe upstream end of the redd. At the downstream end of the redd, a pile of "clean" or recently disturbed loosely packed gravel covers the incubating eggs as described by Reiser and Bjornn (1979).

Spawning surveys wereinitiated at the upstream end of each section and survey personnel recorded the number of paces to each redd and also the total number of paces required to survey the entire section. Average pace length was calculated by dividing the length of stream surveyed (from topo maps) by total number of paces. This allowed the specific location of each redd to be estimated to approximately the nearest 0.1 or 0.2 kilometer. Potential bull trout redds were recorded by survey personnel as either definite, probable or possible using criteria described by Shepard et al. (1982). Only those redds classified as "definite" or "probable" were included in the final count.

CREEL CENSUS AND ECONOMIC SURVEY

A creel census was designed to gather angler use, preference, andharvestdata for Swan Lake, the Swan River (between Swan and Lindbergh lakes), and tributary streams in the drainage. Different sampling designs were used to assess the fisheries of each segment of the drainage because of budgetary andlogisticalconstraints.

Most emphasis was placed on quantifying the lake and river sport fisheries since these were relatively concentrated and were believed to be more intensively utilized than were the tributary fisheries.

Swan Lake and Swan River

The creel census designs for Swan Lake and the Swan River were modified versions of the method described by Neuhold and Lu (1957). The general fishing season on Swan Lake was year-round, hence the creel census covered the period Saturday, May 21, 1983 (opening day of general fishing season) through Friday, May 18, 1984. This sampling period was divided into two-week intervals and, during most of the year, angler counts were made on five of 10 weekdays and on three of four weekend days, all selected at random.

Angler counts on Swan Lake were made twice daily by an observer traveling the length of the lake in a boat during ice-free periods. During the iced-in period, angler counts were made from a series of vantage points established along and on the lake. The starting time for the first count on a given census day was randomly selected on the half-hour without replacement and the second count was made 4-6 hours before or after the first count, depending upon day length.

The Swan Lake sampling design was altered during the periods December through mid-January and mid-March to mid-April because fishing pressure was exceedingly low. During these times angler counts were made once daily on three of four weekend days and on seven (rather than five) of 10 weekdays within each two-week stratum. Fishing parties were located and interviewed between counts by roving the lake or at a check station established in the town of Swan Lake.

The general fishing season on the Swan River began on Saturday May 21, 1983 and ended on November 30, 1983. The season was divided into two-week strata and angler counts were made once daily from a low-flying airplane on five weekdays and on three weekend days selected randomly within each two-week stratum. Fishing parties were contacted for interview information by searching through the study area in a vehicle before and/or after aerial counts; or at check stations set up along the Swan highway, a major thoroughfare that roughly parallels the river (Figure 4). Angler counts on the Swan River and Swan Lake were considered to be instantaneous because each reguired approximately 45 minutes to complete. Neuhold and Lu (1957) concluded that progressive counts requiring less than one hour to complete could be considered instantaneous.

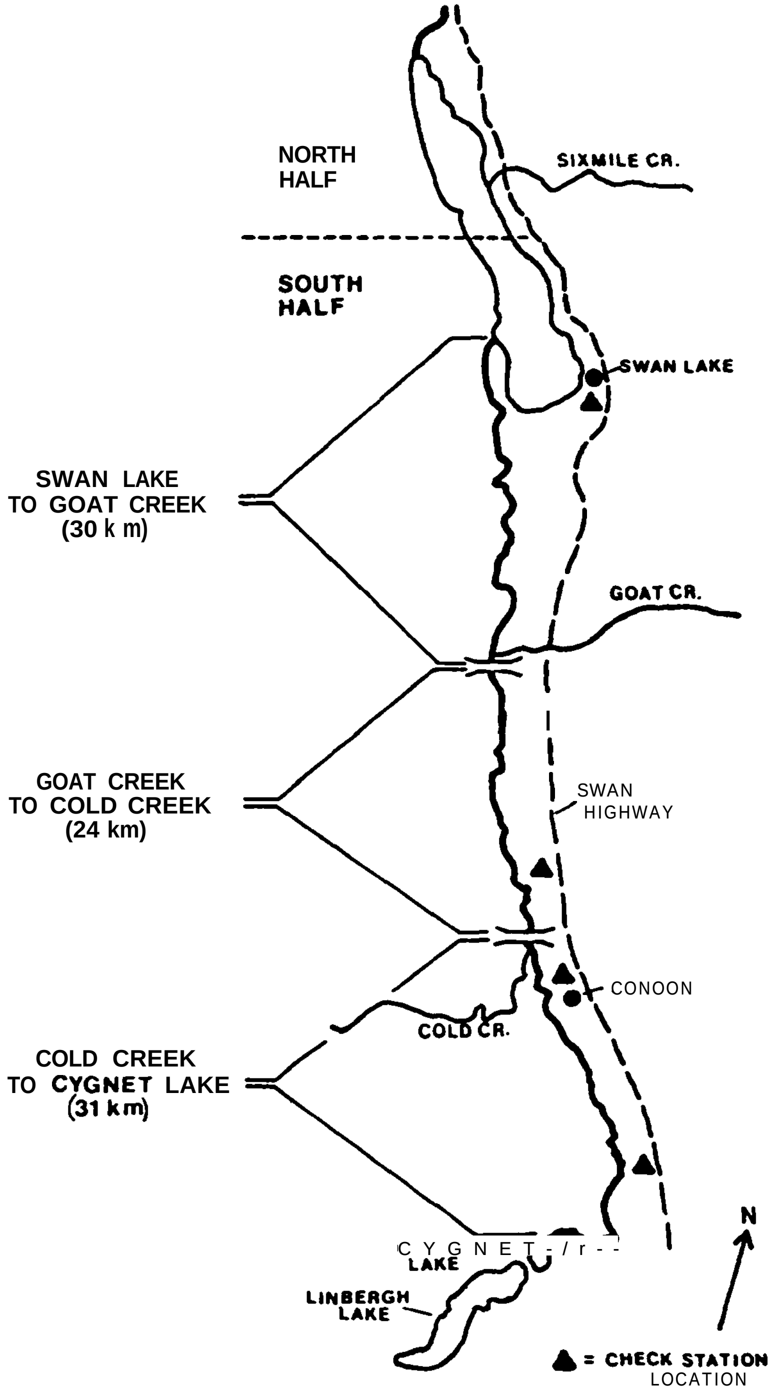

Figure 4. Map (not to scale) of the Swan River drainage, Montana depicting the locations of creel census sections and checking stations.

Swan Tributaries

Because of the large number of tributary streams and size of the study area, it was impractical to conduct a direct creel census of tributary fisheries. Consequently, an indirect method to determine tributary fishing pressure and harvest was devised. This approach relied on the relative amount of tributary versus Swan River fishing effort that was censused at a series of check stations established along the Swan highway (Figure 4). Since Swan River fishing pressure was estimated during the study and was therefore a known quantity, tributary pressure could then be calculated as a percentage of river pressure.

The results of the MDFWP's statewide mail survey of anglers during the period May 1,1982 through April 30,1983 were used to cross-check the above described estimate of tributary fishing pressure. The relative use of Swan Lake versus the Swan tributaries was determined based onthenumber of trips to each area reported by the nearly 14,000 respondents. Fishing pressure on Swan tributaries was then calculated as a percentage of Swan Lake pressure, which was estimated during this study and therefore a known quantity.

Data Analysis

Creel census and fishing pressure data were entered into the Honeywell CP-6 mainframe computer at Montana State University in Bozeman. Fishing pressure and harvest estimates for the Swan River and Swan Lake fisheries were calculated for one-month strata using a computer program developed by the MDFWP. This program incorporates formulae from Neuhold and Lu (1957) to calculate variances associated with fishing pressure, catch rate, and harvest estimates. Angler interview information was also entered into the Discovery microcomputer in the MDFWP office in Kalispell to facilitate summarization of angler characteristics and preferences, seasonal catch rates, size composition of the catch, and other associated parameters.

Economic Survey

Economic survey information was obtained by creel census clerks during the course of interviewing anglers for catch information. A series of 14 questions were designed by ECO Northwest and the MDFWP to gather information from party leaders concerning angler origin, demographics and income, scenic qualities, and other waters fished. The travel-cost method was used to determine the total value to anglers of the fishery resource in the Swan River drainage. This approach involves the construction of a demand curve that shows how the price of the trip (as measured by miles driven to reach the site) affects visitation rate (number of trips made from each origin). The area under the demand curve and above the curve representing average travel cost is the net value of the site to anglers. This net value (also called "consumer surplus") can be defined as the amount that anglers would be willing to pay over and above the cost of the trips themselves to fish at a particular site.

The travel-cost approach is a practical and accepted method for estimating the market value of recreational resources (Palm and Malvestuto 1983). However, it is not well suited for estimating the economic value of specific characterists of a fishing site, such as catch rates, size of fish, species of fish, and scenic qualities. Nor can it estimate the value of changes in those characteristics. The main goals of the economic portion of this study were to determine the net value of potential fish losses induced by small hydro development and compare various estimation techniques.

Four approaches were used to estimate the value of potential fish losses. The first three were contingent-valuation methods that focused on willingness-to-pay (WTP), willingness-to-sell (WTS), and willingness-to-drive (WTD) in response to a hypothetical 25% fish loss (Appendix A-5). The fourth technique, hedonic travel cost, used multiple regression to determine the value of individual characteristics of sites. The characteristics considered were catch rate (number of fish caught per day), average size of largest fish in catch, scenery, percent trout as target species, percent bull trout as target species, type of water, and management strategy. Interview information from eight other fishing areas in Montana was gathered by cooperating MDFWP biologists to add diversity to the database. Information from 920 fishing parties was used in these analyses. Of these parties, 376 were interviewed in the Swan drainage and 544 were from other waters. Specific information regarding the methods and questionnaire used in the economic valuation study were detailed by ECO Northwest (1984).

HYDROLOGY AND INSTREAM FLOW NEEDS

Flow Gaging

Continuous water level recorders were installed within or near the diversion areas of proposed micro-hydro sites on South Fork Lost, Soup, Squeezer, Lion, Piper and Cold creeks during November, 1982. Vertical four-inch diameter slotted steel standpipes with welded points were driven approximately two feet into streambeds using a semiportable tripod-type pile driver powered by an electric motor. Standpipes were capped with a threaded iron platform upon which Belfort Type Fw-1 water level recorders were mounted. The platforms and recorders were covered with a locking steel cap and staff gauges were attached to the standpipes. The Squeezer Creek recorder was installed by attaching the stand pipe to a bridge abutment.

Water level recorders were calibrated by means of monthly streamflow measurements and associated staff gage readings. Streamflow measurements were made using Teledyne-Gurley AA current meters or Teledyne-Gurley Pygmy current meters using standard techniques (United States Geological Survey 1969). Daily average and maximum flows were estimated from water level recorder charts using stage versus discharge relationships derived from linear or log-log regression equations, or from curves fitted by eye.

Flow duration curves for each gaging site were constructed for the water year October 1, 1983 through September 30, 1984 once the exceedance percentage for each daily mean flow was determined. Daily discharges during winter months (November through March) were estimated by interpolation of monthly discharge measurements because ice conditions frequently caused erratic water level fluctuations and occasionally damaged staff gages. Tabulations of average daily flows and graphs of average weekly streamflows and flow duration data are presented in Leathe et al. (1985a). The specific locations of gaging stations may be found in Leathe et al. (1985b).

Instream Flow Needs

The amount of reserved instream flow required to preserve existing fish populations in 17 Swan tributary streams was determined using the wetted perimeter method described in Nelson (1984). This technique involves the identification of inflection points on a computer-generated composite wetted perimeter versus discharge curve. The curve is derived from measurements on three or more riffle cross-sections in a given stream as detailed in Leathe and Graham (1983). Comparisons were made between the WETP technique and the IFG1 method (Milhous 1978) during 1982 and were discussed by Leathe and Graham (1983). Wetted perimeter versus discharge curves for Swan tributaries with recommended minimum flows are presented in Leathe et al. (1985a) and specific measurement sites may be found in Leathe etal. (1985b).

SEDIMENT ANALYSIS

To analyze the effects of increased stream sedimentation due to development activities in the Swan drainage, it was necessary to construct a watershed sediment model. Such a model could then be used to predict the cumulative impact of future forest development and proposed micro-hydroelectric installations on stream habitats, and ultimately, fish populations.

Development of Coefficients

Natural Erosion

The amount of sediment reaching a stream is primarily a function of erosion rates from adjacent landforms. Even undisturbed hillsides and streambanks contribute substantial amounts of material to waterways (Anderson 1975, Megahan 1975, Madej 1982). Debris avalanche, mass wasting, surface creep, overland flow, and channel erosion are the major processes by which sediment is transported to lower order stream channels in mountainous terrain (Megahan 1981, Wilson et al. 1982). Climatic events such as floods, windstorms, and fires have a dominant influence on the types and extent of erosional processes (Swanston 1980).

Landtypes are the basic units of watershed analysis; they are defined as areas of land with similar landform, parent material, soil, and vegetation characteristics (Wilson et al. 1982). Because these characteristics also determine the hydrologic function of slopes, landtype classifications can be used to estimate erosion rates.

Soil scientists have completedaland systems inventory for the Swan Lake Ranger District (USDA, Forest Service 1980) and, together with hydrologists, have compiled estimates of natural sediment delivery rates to stream channels for all landtypes identified (Appendix B-7). Land units were classified at the landtype level for all non-wilderness areas and at the landtype association level for wilderness. Sediment delivery rates were calculated by considering slope, precipitation, infiltration rates, soil composition, bedrock type, proximity to stream, erodibility of surface particles, and delivery efficiency. All material which could be transported to streams was considered in calculating sediment loads. This consisted mostly of sand, silt, and clay, but included gravel and larger material on very steep landtypes.

Man-induced Erosion

Ground-disturbing activities such as road building and timber harvest usually accelerate natural erosion rates (Yee and Roelofs 1980, Chamberlin 1982, Megahan 1981). During the course of forest planning, specific coefficients were developed to predict sediment production from disturbances on each landtype (Appendix B-7). These estimates were based on adherence to current Forest Service standards and practices. Road-relatedsedimentwas estimated using average acres of ground exposed in road surface, cut slope, fill slope, and drain ditches. Estimates of logging-related sediment were based on averages of skid trail widths, log landing size, and fireline widths required for clearcutting. "Seed tree" and "shelterwood" cuts were included in the clearcutting category. Selective removal, low-volume salvage logging, and commercial thinning involved much less ground disturbance and were not evaluated.

Recovery rates were calculated for all disturbances based on expected rates of revegetation and slope stabilization. Road sediment was expected to decline steadily to a threshold level by the fifth year after construction. Maintenance projects (blading and ditch cleaning) would reactivate some sediment production. Skid trails were considered fully recovered after ten years, firelines after two, and sediment from log landing sites was expected to drop to a threshold level after three years. All coefficients were expressed as tons of sediment delivered to perennial stream channels per mile or acre of disturbance per year. Coefficients were specific to landtype and age of ground disturbances.

In order to adapt this system to a sediment prediction model, various adjustments and assumptions were made. Periodic road maintenance was assumed to be the primary sediment-producing activity on all existing "collector-type" roads. These roads were assigned a maintenance code of one, two, three, or four-plus based on the frequency of past maintenance work. Because maintenance activities can not be predicted specifically by year, an average annual sediment rate was computed over the maintenance cycle for each category. For example, a collector road in the "three" maintenance category in the model would annually produce sediment equal to the average of its three year total, which includes one year of maintenance and two succeeding years of recovery. Road coefficients are given by landtype and maintenance category in Appendix B-8.

"Local-type" roads, which branch out from the collector trunks, were given a sediment coefficient based on their age (i.e., recovery status). Maintenance was assumed to occur about every ten years on these roads. Therefore all local roads over ten years old were given a sediment coefficient equal to the average of their ten-year maintenance cycle, that is, the average of one maintenance year sediment plus nine years of progressive recovery.

A more complex procedure was required to evaluate reconstruction of existing roads. Reconstruction projects typically involve as much ground disturbance as initial construction. Therefore, rebuilt local roads were assigned a new age based on the year of reconstruction. For reconstructed collectors, initial sediment production was also estimated based on their new age. However, once a rebuilt collector reached the age of its anticipated maintenance frequency, it was shifted to the appropriate sediment coefficients for that maintenance category. This could be different than its previous maintenance category. Local roads reconstructed to become collectors were treated in the same manner. Minor reconstruction projects were considered to be covered under maintenance activities.

Ground disturbance during timber harvest occurs primarily on skidtrails, landings, and firelines. To estimate sediment production, assumptions were made concerning the location of roads, skidtrails, and firelines required for logging. Hypothetical rectangular clearcut units of two, ten, and forty acres were evaluated. These were the standard unit sizes used in forest planning.

On roadable landtypes, units were located between an assumed road spacing of 1,000 feet and skid trails were plotted perpendicular to roads at intervals of 200 feet. On several landtypes characterized by low timber volumes, skid trail density was estimated at one-third that of more productive sites.

Log landing requirements were assumed to be one-half, one, and two acres for two, ten and 40-acre clearcuts, respectively. On steeplandtypes, suspended cable systems would be used to harvest trees (no skid trails) and roads would be used for landings.

Fireline lengths were estimated for ten and 40-acre clearcuts; pile burning (no firelines) was assumed to be the slash disposal method used on two-acre clearcuts. In most cases, firelines would be construct& by tractor around the perimeter of a cutting unit, except where roads would serve as fire breaks. On steep landtypes, firelines would be dug by hand to one-half the width of tractor lines and have a correspondingly lower sediment coefficient.

The final results of these simulations for three clearcut sizes are given in Appendix B-9. Coefficients for logging-related sediment, then, are expressed as tons per clearcutacre per year and include skid trail, landing, and fireline cycles for all three disturbance types. Coefficients (tons of **sediment per acre per** year) for the three modeled clearcut sizes were assigned to larger size categories to include all possibilities: two-acre coefficients for l-5 acre units, ten-acre coefficients for 6-20 acre units, and forty-acre coefficients for >20-acre units. Landtypes not suitable for clearcutting were not analyzed.

Sediment From Hydroelectric Development

Sediment coefficients for the construction of microhydroelectric projects were developed by considering the associated ground disturbances. Visits were made to two existing projects - USFS Addition Creek hydro project (completed) and the Whitefish hydro project (under construction at the time) - to gain an understanding of actual impacts.

All proposals specify burial of the penstock and transmission line whenever possible. Road construction coefficients were used to model penstock installation since the corridors are similar to roads in width and initial function. However, no "maintenance' sediment coefficients were used for the pipeline routes: instead, it was assumed that sediment production would decline steadily to a minimum level as do unmaintained roads. Re-excavation of a penstock for repair wouldviolatethis assumptionand require a new recovery schedule. Road sediment coefficients may in fact be too conservative for estimating sediment from penstocks, which are typically installed at steeper grades than logging roads. Also, a penstock rupture could trigger catastrophic slope failure and result in severe stream sedimentation.

Transmission line burial was simulated by applying the coefficients for tractor-excavated firelines (one-fifth road width). This type of disturbance generates relatively minor amounts of sediment and is assumed to be fully recovered after two years.

Sediment produced during construction of diversion dams and powerhouses was not modeled. It was assumed that mandatory protective measures (coffer dams, lined bypass channels, etc.) would be imposed to minimize sedimentationduringthe construction of diversion dams. These impacts should be short-lived. Sediment from powerhouse construction was ignored because the disturbance area is very minor in comparison to penstock corridors.

Access roads would be needed for proposed powerhouses not adjacent to existing or planned roads. The standard sediment coefficients for local roads were applied to all new access roads.

Composition of Drainage Basins

In order to estimate sediment production, complete inventories of landtype acreages were made for all proposed project streams and for the Elk and Glacier Creek drainages. The latter two streams were included because Elk Creek was an important bull trout spawning stream and Glacier Creek was considered potentially important for bull trout. Drainage basin boundaries for each reach of stream were delineated on a topographic landtype base map (scale 1:63,000). Upstream basin boundaries were drawn at the upper reach boundaries along topographic breaks moving upslope from channel banks. Lakes at the heads of drainages were considered sediment traps and basin boundaries were drawn immediately below them. Total acres of each landtype within each reach basin were determined on a Numonics 2400 digitizer. Separate tallies were kept for five ownership categories: Rational Forest non-wilderness, National Forest wilderness, Plum Creek Timber Company, State of Montana, and other ownership.

Using a transportation system base map and a landtype overlay, all existing roads were measured with a Numonics electronic graphic calculator/planimeter. Road mileage within each reach basin was measuredtothe nearest O.l mile for each landtype and ownership category. Type of road and approximate year of construction were also recorded for each road segment. Roads older than ten years were coded as being built in 1970 for simplification.

A history of timber harvest activities on National Forest land was compiled for each reach basin by reviewing the timber stand data base. All timber stands were first assigned a landtype code. Stands that overlapped landtype boundaries were assigned the landtype occupied by the majority of their acreage. Finally all timber stands harvested by clearcutting in the last ten years were recorded. Size of stand (acres) and year of treatment were noted.

Adequate records of timber cutting on Plum Creek Timber and Swan State Forest lands were only available for 1977 and later years. Size of cutting units and year of harvest were obtained from these records. Locations of units by reach basin andlandtype were determined by cross reference to base maps.

Sediment Prediction Model

Existing Relationships

A computer program was developed to calculate both natural and development-related sediment loads for the study drainages. Information about landtype composition, logging activities, and road building in each stream reach was first assembled in a data file. The program then references sediment coefficient files arranged by landtype to compute annual sediment loads for all reaches. The user must specify a year of interest and an age limit on roads and logging units to include. Sediment from upstream reaches and tributaries can also be included if desired. A description of the program is given in Appendix B.

A review of pertinent literature was made to gather techniques for relating sediment production to streambed composition. Comprehensive sediment routing requires historical and site-specific data on flood frequency, mass wasting, debris flows, bedload transport, and channel storage (Swanson etal. 1982a). Such an analysis was beyond the scope of this study. Hence, we used regression techniques to look for empirical relationships between various measures of watershed condition and streambed conditions measured in the 1983 stream habitat surveys. Because channel gradient plays a major role in sediment dynamics (Heede 1980), it was included as an independent variable in most of the tested regressions.

Two categories of percent fines, O-2.0mm and O-6.4mm, were tested as dependent variables. Only results for percent fines O-6.4mm are reported, since this is the size range mostoftencited in fisheries literature and is likely to involve less observer error. Also tested was a combined rating of particle size and embeddedness called "substrate score" (Crouse et al. 1981). We omitted the ranking of material surrounding the dominant substrate particles because of difficulty in field application. Therefore, our substrate score is a summation of three ranks: dominant particle size, subdominant particle size, and embeddedness (Table 3).

Table 3. Substrate characteristics and associated ranks for computing substrate score (modified from Crouse et al. 1981).

Rank	Characteristic
	Particle size class [a]
1	Silt and/or detritus
2	Sand (<2.0 mm)
3	Small gravel (2.0 - 6.4 mm)
4	Large gravel (6.5 - 64.0 mm)
5	Ccbble (64.1 - 256.0 mm)
6	Boulder and/or bedrock (>256.0 mm)
	Embeddedness
1	Completely embedded or nearly so
2	3/4 embedded
3	l/2 embedded
4	l/4 embedded
5	Unembedded

[a] Used for both dominant and subdominant particle ranking.

The following determinant variables were tested separately by regression using the 1983 data set from 46 study reaches for which both sediment analysis and habitat surveys had been done:

1. annual natural sediment load
2. annual road-related sediment load
3. annual logging-related sediment load
4. annual total sediment load
5. annual total sediment load per acre drainage basin
6. percent of drainage basin in roads and/or clearcuts (after Cederholm et al. 1980)
7. percent increase over annual natural sediment loads: road-related sediment
8. percent increase over annual natural sediment loads: logging-related sediment
9. percent increase over annual natural sediment loads: road and logging-related sediment
10. three year average percent increase over natural sediment loads: road and/or logging sediment
11. five-year average percent increase over natural sediment loads: road and/or logging sediment.

Various methods of computing sediment contributions from upstream reaches were also tested. These included adding in all sediment from upstream reach basins, only sediment from the reach basin immediately upstream, and a routed portion of upstream drainage basin sediment. The method used to route sediment was described by Cline etal. (1981). Sediment delivery ratio is based on size of upstream drainage area, which is considered to be an index of in-channel sediment storage capacity (Roehl 1962, Royce 1975). The following equation was used to derive routing coefficients:

$$Y = X^{-0.18}$$

where: Y = channel sediment routing coefficient, and
X = upstream drainage area in square miles.

Regression equations providing the best fit between calculated sediment loads and stream substrate conditions were chosen to model future impacts. Standard logarithmic transformations, square functions, and variable cross-products were also tested for improvement in correlation coefficients.

Future Roads

Timber sale planning maps were used to plot future road construction and reconstruction projects on National Forest System lands in the study area. Future road projects were assigned a year of construction based on the best judgment of transportation planners. Information was available to reliably simulate road development activities through 1991, after which planning data is not specific enough for the needs of this model.

The majority of non-federal land in the study area is owned by the State of Montana (Swan River State Forest) and Plum Creek Timber Company. Road building plans for the State Forest were available through 1984 only. Further expansion of the road system could not be predicted and is therefore not included in estimates of future sediment loads. However, only limited new road construction on the State Forest is anticipated.

Plans for new roads on Plum Creek Timber Company lands are kept confidential except for those in cost-share agreements with the Forest Service. Although the future pace of road construction and logging will likely be governed by economic considerations, Plum Creek seems to be accelerating harvest volumes while minimizing capital investment in new roads. If this trend continues, sediment from road maintenance will increase while that from new construction will decrease. If on the other hand, access into new areas is rapidly developed, road construction sediment will increase and maintenance sediment may decline. Without drainage-specific planning information, sediment production from new non-cost-share Plum Creek roads could not be included in the model. As a result, future sediment loads will probably be underestimated in drainages with Plum Creek ownership. However, major road systems in these areas are usually cost-shared with the Forest Service. The main collector system is already in place and programmed into the sediment analysis based on expected maintenance frequencies. Therefore, the lack of planning data from Plum Creek Timber Company should not compromise cur results.

Hydroelectric Development

Maps submitted in preliminary permit applications were used to plot locations of proposed micro-hydroelectric projects on landtype/reach basin maps. Penstock lengths, transmission lines, and likely access roads were measured to the nearest one-tenth mile using a Numonics planimeter. The hydroprojects were evaluated for their individual impacts by entering them into the predictive sediment model for five different years -- 1986 through 1990 -- with all construction being completed during the year of entry. Construction could not feasibly start before 1986 because of application and review periods, and the impacts of projects built after 1990 would extend beyond the period coveredbyother planning data. In any case, themodelassumes that impact from sediment production begins one year after construction, because most sediment is delivered to streams during spring runoff. This analysis allowed the comparison of impacts between projects as well as between years.

Additionally, various levels and rates of hydroelectric development were evaluated. Seven separate scenarios ranging from no development to full immediate development were run through the model (Table 4). In all scenarios except "No Development", project construction was initiated in 1986. Rate of development of multiple projects varied, but all scenarios had to be completed within five years to keep impacts within the planning horizon.

To establish a logical sequence of construction, the sites were ranked primarily by developer interest and secondarily by cost estimates (Table 5). Status of permit applications with FERC was used as an indicator of developer interest. Projects with active preliminary permits were ranked category 1, those for which the developer expressed an intent to refile were ranked category 2, those with expired or uncertain filing status were ranked category 3, and those projects whose permits had been formally surrendered (as of 9/30/83) were grouped category 4.

Within developer interest categories, the sites were ranked according to a crude index of relative partial cost per unit of potential power. Powerhouse and diversion structure costs were assumed to be similar among the projects and were therefore ignored. Penstock and transmission line costs were estimated using permit information and graphs given in Cunningham (1982). Costs for construction of minimum-standard access roads were estimated at an average of $15,000 per mile, based on the judgment of Forest Service engineers. Geological differences between sites that may affect project development costs were not considered. The final ranking may not be entirely accurate; it is intended only to generate reasonable examples of a wide range of potential development schemes.

WATER YIELD

Although forest development frequently produces changes in streamflows, the effects vary widely between streams and are difficult to quantify, partly due to the large variability in natural streamflows and the multitude of hydrologic processes affected by timber harvesting (Harr 1980). In general, water yields increase after tree removal because canopy interception of rain and snow is eliminated and soil moisture content rises with decreased transpiration (Rothacher 1973, Chamberlin 1982). Although low flows are usually more affected than high flows, logging roads can increase the surface drainage network of a basin and magnify peak flows (Hsieh 1970). Increases in runoff after harvesting can substantially raise summer streamflows (Chamberlin 1982).

According to the Proposed Flathead Forest Plan, future timber harvests will be managed to protect water quality and prevent deterioration of streambanks. Water yield increases are not expected to exceed natural runoff by more than 12 percent in any stream and none of the Swan study streams is considered to be in risk of hydrologic damage. Therefore, the effects of future flow

Table 4. Description of micro-hydro development scenarios. Construction would begin in 1986.

Scenario	No. of projects developed[a]	Rate of deve1opnent
No development	None	---
Low incremental	Four	the proj ect/year
Low immediate	Four	Four projects/year
Moderate incremental	Ten	Two projects/year
Moderate immediate	Ten	Ten projects/year
Full incremental	Twenty	Four projects/year
Full immediate	Twenty	Twenty projects/year

[a] Order of development determined by rank (Table 5).

Table 5. Ranking of proposed micro-hydro projects in the Swan River drainage.

Project	Interest category	Relative cost index (per rated kw capacity)	Rank
Squeezer	1	1350	1
Piper	1	2830	2
Cedar	2	2030	3
Cold	2	2400	4
Hall	3	990	5
Sixmile	3	1930	6
S. Woodward	3	2540	7
Bond	4	1190	8
Groom	4	1230	9
scout	4	1380	10
Porcupine	4	1530	11
Soup	4	1770	12
Bethal	4	1920	13
Goat	4	1990	14
Lion	4	2230	15
S. Woodward trib.	4	2380	16
Lime	4	2890	17
Yew	4	3250	18
N.F. Lost	4	3690	19
S.F. Lost	4	3760	20

increases on fish habitat were considered minor in comparison to sedimentationandwerenotincluded in this assessment.

ON-SITE INVESTIGATIONS

Limited measurements of water temperature and dissolved gasses were made at two operating small hydro projects in northwestern Montana &ring the late summer of 1984. These measurements were made in order to identify problems that might result from project operation.

The Whitefish hydro project is a recently completed retrofit of the city's municipal water supply system. This project has a rated capacity of 160 KW with about 690 feet of gross head and involves diversion structures on two headwater streams. The diverted waters are combined and pass through a 12,500 foot long buried penstock that tapers from 15-inch diameter at the upper end to 12-inch at the lower end. The water is forced through small diameter high pressure nozzles to produce jets which drive a Pelton wheel. After passing through the powerhouse, the water enters the small municipal reservoir which drains into Whitefish Lake rather than back into the stream (Haskill Creek) from which the waters were diverted. Continuous recording thermographs were placed above each of the two diversions and in the powerhouse outfall to monitor temperature changes that may result from diversion through the underground penstock. Gas saturation measurements were made at these three sites on two dates (late August and mid-September) using a hand-held Weiss saturometer and methods described by Fickeisen etal. (1975).

The USFS Addition Creek hydro project is a SO KW facility that was constructed between 1979 and 1982 to supply electricity to the Spotted Bear Ranger Station near the South Fork of the Flathead River. This project consists of a concrete diversion structure and two 15 inch buried penstocks that are 2900 feet long andprovide 129 feet of gross head. Diverted water is returned to the stream approximately 200 feet below the powerhouse. The powerhouse is equipped with a cross-flow turbine similar to that described by Gloss and Wahl (1983). Continuous recording thermographs were placed above the diversion dam, in the powerhouse outfall, and in the partially dewatered stream channel immediately above the diversion return. Gas saturation measurements were made at these three sites on two separate occasions.

RESULTS AND DISCUSSION

FISH POPULATIONS AND BIOLOGY

Tributaries

Abundance and Distribution

Fish population sizes were determined by electrofishing on 74 tributary reaches. Cutthroat and brook trout were the most widely distributed species, being found in 45 and 40 reaches, respectively, while bull trout were present in 31 reaches. Maximum observed brook trout densities (more than 600 fish 75 mm and longer per 300 meters of stream) were much larger than peak cutthroat or bull trout densities (285 and 270 fish per 300 meters, respectively). With the exception of migratory adult bull trout, tributary fish were relatively small, ranging for the most part between SO and 200 mm (Figure 5). Fish longer than 200 mm (8 inches) typically comprised four to six percentofthetotal fish captured by electrofishing in tributaries.

Fish species abundance and distribution within tributaries to the Swan River appeared to be strongly influenced by channel gradient (Figure 6). Brook trout were by far the most abundant species in low gradient (0 to 3%) reaches while cutthroat trout predominated in higher gradient headwater reaches. Bull trout were not a dominant species in any gradient category but tended to be most abundant in reaches having gradients of six percent or less (Figure 6).

Both Griffith (1972) and MacPhee (1966) observedthatbrook trout tended to displace cutthroat trout in low gradient stream reaches in Idaho. Griffith (1972) believed that the relative success of brook trout in these areas was related to differential vulnerability to angling and to a brook trout size advantage. The fry of fall-spawning brook trout emerge from the gravel much earlier in the year than fry of spring-spawning cutthroat trout and are consequently able to attain larger size during their first year of life. The ability of brook trout to populate low gradient stream habitats in relatively large numbers and the size advantage they possessed were probably the primary factors responsible for their dominance over cutthroat in low gradient stream reaches in the Swan drainage.

An estimate of thetotalnumber of each of the three species of trout inhabiting the tributary system was made in order to facilitate the process of cumulative impact prediction. For the 74 reaches that were electrofished, this simply involved expanding the population estimates over the entire length of the reach. The 28 reaches that were not ground surveyed were classified into the gradient and drainage area categories used in our reach subsampling scheme. The population density of each trout species in each of

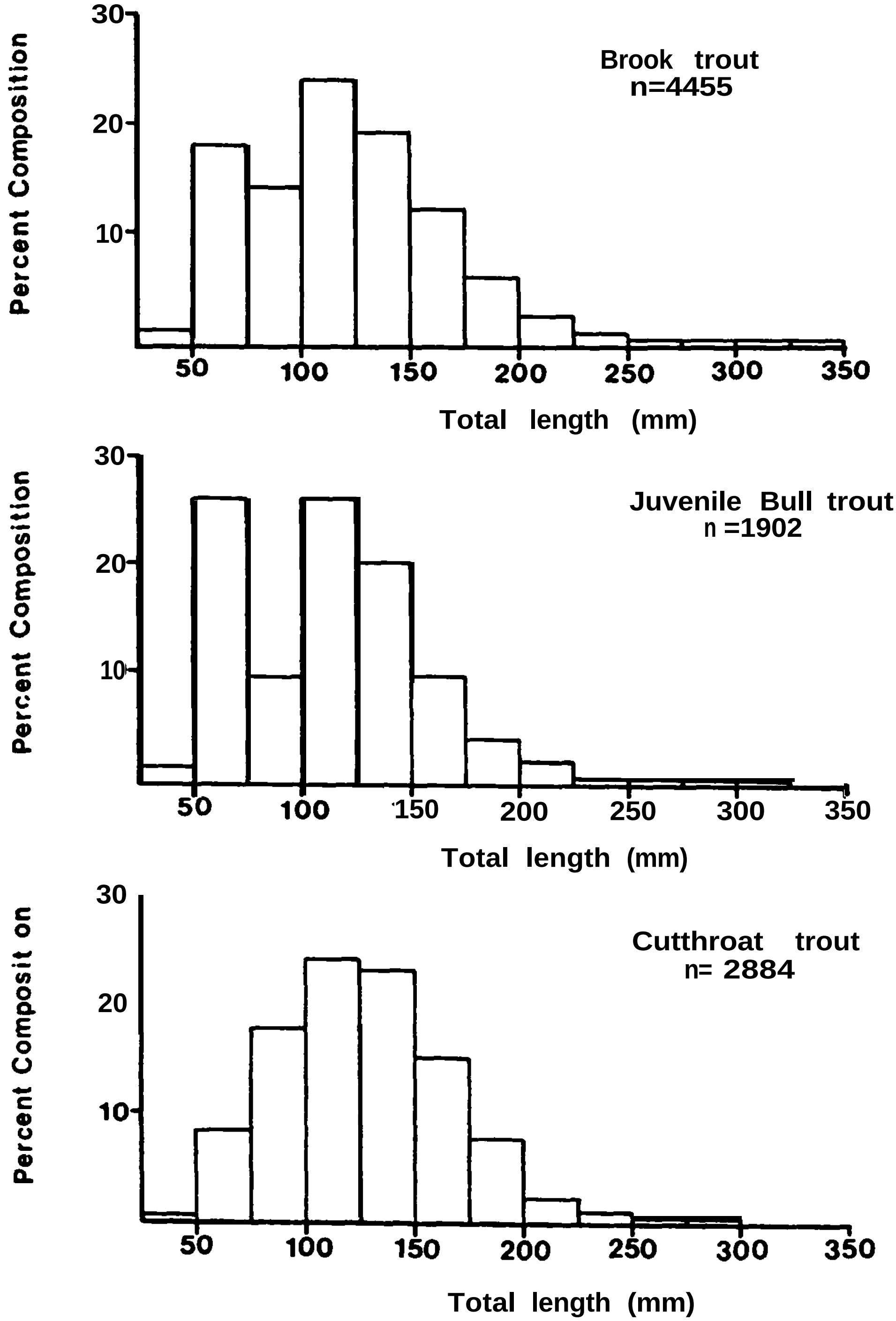

Figure 5. Length frequency distributions of brook, bull, and cutthroat trout captured by electrofishing in Swan tributaries during the period 1982 through 1984.

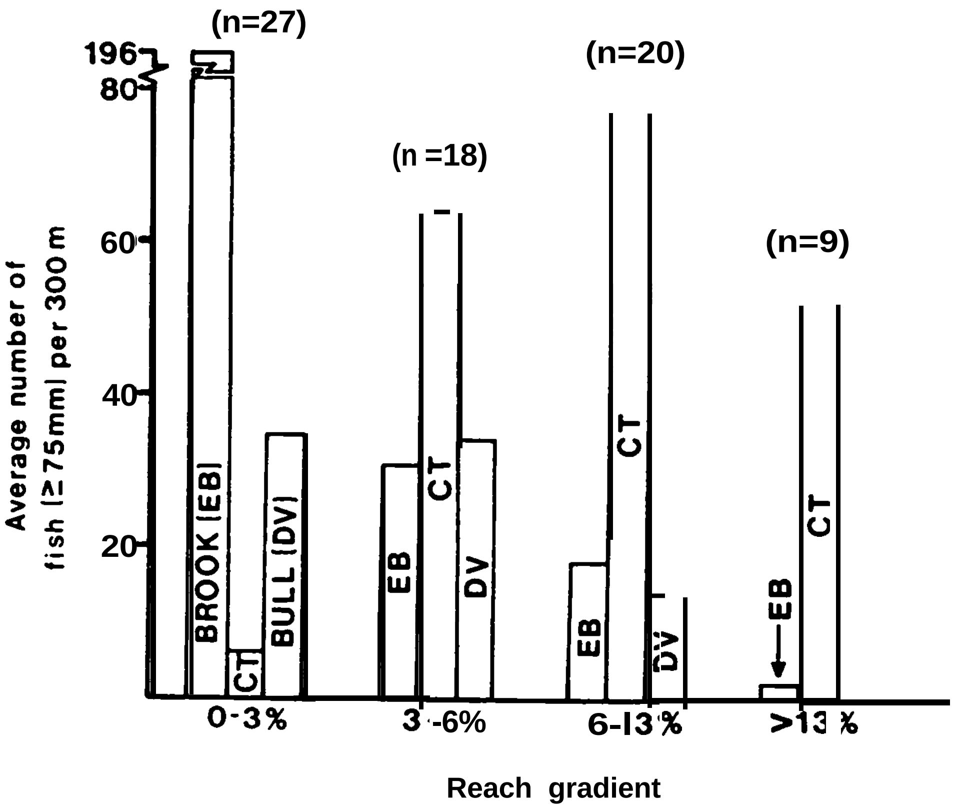

Figure 6. Average population density (number of fish 75 mm and longer per 300 m of stream) of three trout species in tributaries to the Swan River in relation to channel gradient. Sample sizes (number of reaches electrofished) are in parenthesis.

the 28 unsurveyed reaches was then estimated using average fish population densities for each gradient-area category determined from field electrofishing surveys (Table 6). In a few instances it was intuitively obvious that a particular species did not inhabit a particular unsurveyed reach based on information gathered in adjacent (i.e. upstream and/or downstream) reaches. In these cases the density of the species in question was assumed to be zero.

Using the procedure described above, it was estimated that the tributary system within the study area supported approximately 107,000 brook trout and 65,000 cutthroat trout. A total population of 31,000 stream dwelling bull trout was estimated, however, this number probably included a significant number of stream-resident fish and fish of undetermined origin. A different procedure (described in the Cumulative Impact Analysis section of this report) was used to estimate the population size of migratory juvenile bull trout and to predict the cumulative effects of small hydro development on these fish.

Habita Preference

Stepwise multiple regression analysis identified five habitat variables that together accounted for 80% of the variation in juvenile bull trout density in 21 Swan tributary reaches (Table 7). Streambed substrate score was the most influential variable in the model, accounting for 34% of the variation in bull trout density (Table 7). The remaining four variables (maximum pool depth, total instream cover, drainage area, and channel debris) together accounted for the remaining 46% of total variation in bull trout density. The positive correlation with substrate score suggested that juvenile bull trout preferred streams having relatively coarse and unembedded streambed materials. High juvenile bull trout densities were also associated with relatively deep water in smaller streams having large amounts of instream cover (primarily cobbles and boulders) and low amounts of channel debris.

A significant relationship was obtained between cutthroat trout density and three stream habitat variables measured in 35 tributary reaches (Table 7). The negative coefficients assigned to maximum depth and drainage area indicate that high cutthroat densities were most often found in small streams. Maximum depth and total instream cover accounted for most (39%) of the variation in cutthroat density in tributary reaches.

Total instreamcover was foundtobe the single most important environmental variable influencing brook trout density in 33 tributary reaches (Table 7). Although it is likely that other variables were important in determining brook trout abundance, their incorporation into the analysis did not add statistically significant predictive power.

Table 6. Average fish population size (number of fish 75 mm and longer per 300 mm of stream) in reaches within various gradient and drainage area categories in Swan River drainage tributaries. Standard deviations are in parenthesis.

Gradient %	Drainage area (km^2)	Number reaches sampled	Ave. no. fish ≥75 mm per 300 m (±SD)		
			Cutthroat trout	Brook trout	Bull trout
0-3%	0-20	3	11(±14)	490(±103)	0(±0)
	>20-50	13	6(±12)	154(±89)	22(±36)
	>50	11	5(±10)	164(±177)	59(±73)
3-6%	0-20	8	104(±86)	49(±69)	0(±1)
	>20-50	9	42(±55)	22(±60)	59(±89)
	>50	1	0	0	108
6-13%	0-20	14	81(±85)	1(±2)	8(±21)
	>20-50	5	73(±116)	44(±65)	24(±54)
	>50	1	39	129	39
>13%	0-20	9	57(±58)	3(±8)	0(±0)
	>20-50	—	—	—	—
	>50	—	—	—	—

Table 7. Stepwise multiple regression models that describe the relationships between trout density (number of fish 75 mm and longer per 100 square meters) and stream habitat variables for tributary reaches in the Swan River drainage.

Species	Variables	Partial correlation	Slope	Significance (p-value)
Bull trout	Reach substrate score	0.71	0.71	<0.01
(R^2=0.81, n=21,	Maximun pool depth	0.79	0.12	<0.0l
$p<0.05$)	Total instream cover	0.58	0.08	0.01
	Reach drainage area	-0.65	-0.07	<0.0l
	Channel debris	-0.59	-0.06	0.01
Cutthroat trout	Maximun depth	-0.48	-12.60	<0.0l
(R^2=0.46, n=35,	Total instream cover	0.53	0.32	<0.0l
$p<0.05$)	Reach drainage area	-0.34	-0.10	0.01
Brook trout	Total instream cover	0.53	0.39	<0.0l
(r=0.53, n=33,				
$p<0.05$)				

Swan River

Fish population estimates were obtained in two sections of the Swan River during the fall of 1982 to determine the distribution and abundance of migratory cutthroat and bull trout. Rainbowand brook trout were the dominant species in a 457 meter section of the upper river immediately below Cygnet Lake, a small lake slightly downstream from Lindbergh Lake. These fish were relatively small and ranged up to 280 mm (11 inches) total length. Population densities of rainbow and brook trout larger than 75 mm were 210 and 190 fish per kilometer (338 and 304 per mile), respectively. Very few cutthroat and no bull trout were captured.

Rainbow and brook trout were also the dominant species in a 6 km (3.7 mile) section in the middle portion of the river, between the Salmon Prairie and Piper Creek bridges. The fish were generally larger in this portion of the river, rainbow trout ranged up to SO2 mm (19.8 inches) and brook trout up to 269 mm (10.6 inches) total length (Leathe and Graham 1983). Population estimates were made only for fish larger than 150 mm (6 inches) due to gear inefficiency and low fish densities and were 187 and 155 fish per kilometer (301and 249 per mile) for rainbow and brook trout, respectively. A few juvenile bull trout and only two cutthroat trout were captured, suggesting that significant use of the river by these species for anything other than a migration corridor between the tributaries and Swan Lake was unlikely. Further, the examination of stream trapping, lake gill netting, and angler harvest information in conjunction with river electrofishing results suggests that the Swan River drainagecurrentlysupports a very limited number of migratory westslope cutthroat trout.

Swan Lake

Agillnetsurvey of Swan Lake was conducted during April of 1983 to determine the distribution and abundance of gamefish and the status of migratory bull and cutthroat trout. Peamouth and northern squawfish were the most numerous species captured,together comprising 60% of the floating net catch and 76% of the sinking net catch (Table 8). Rainbow trout outnumbered cutthroat trout in floating and sinking net catches. Shoreline net sets were ineffective in capturing kokanee salmon which are known to be abundant in the lake and were the dominant species in the sport fishery, as will be discussed later. Swan Lake kokanee do not use the river system for reproduction.

Catch rates for westslope cutthroat trout in floating gill nets were very low (0.3 per net) incomparison to catches made in nearby Flathead Lake (more than 3.0 per net) during a similar time period (Leathe and Graham 1982). This indicated that a relatively small population of cutthroat trout inhabited Swan Lake in spite of the fact that the lake received plants of 30,000 to 50,000 fingerlings (four to six inches) in most years since 1975. The bull

Table 8. Gill net catch information for Swan Lake during April of 1983.

Species	Floating nets Total catch	Floating nets Catch per net	Sinking nets Total catch	Sinking nets Catch per net
Rainbow trout	8	0.7	2	0.2
Cutthroat trout	3	0.3	0	0
Rainbowx cutthroat	2	0.2	2	0.2
Bull trout	3	0.3	44	3.7
Brook trout	1	0.1	1	0.1
Kokanee salmon	1	0.1	0	0
Mountain whitefish	5	0.4	13	1.1
Northern pike	4	0.3	7	0.6
Northern squawfish	19	1.6	131	10.9
Peamouth	43	3.6	198	16.5
Largescale sucker	9	0.8	23	1.9
Longnose sucker	0	0	11	0.9
Yellow perch	2	0.2	1	0.1
Total	100	8.6	433	36.2

trout catch in sinking nets (3.7 fish per net) was similar to catches from Flathead Lake where bull trout are a popular sport fish (Leathe and Graham 1982, Graham and Fredenberg 1983). Most of the bull trout captured in Swan Lake were taken in the north and middle sections whereas nearly all of the 11 northern pike were captured in the shallow, weedy south end.

Age and Growth

Growth rates of trout in the Swan River drainage varied markedly between species and areas. Tributary cutthroat trout (from Cedar, S.F. Lost, Soup, and Groom creeks) were the slowest growing fish in the drainage, requiring four years to attain a length of 151 mm (about six inches; Table 9). Based on the examination of scales and otoliths it was estimated that from 75 to 80% of tributary cutthroat did not form a first annulus on their scales, indicating a very slow growth rate. This percentage was higher than that reported for cutthroat in tributaries to the North and Middle Forks of the Flathead River (61% missing; Fraley et al. 1981). Information on fish tagged in Soup Creek during April of 1983 and recaptured in November of the same year indicated that cutthroat trout grew much more slowly than did brook trout, even in the same stream. Cutthroat ranging between 100 and 130 mm total length in April grew an average of 19 mm (SD=$\pm$6 mm: n=23) by November while brook trout in the same size range grew an average of 39 mm (SD=$\pm$6 mm; n=7).

Brook trout grew rapidly during the first two years of life in the middle section of the Swan River (Table 9) but fish longer than 250 mm were relatively rare in the population (Leathe et al. 1985a). This may have been largely due to natural mortality since these fish matured at an early age. Almost all of the ripe female brook trout captured by river electrofishing during the fall of 1982 ranged between 125 and 180 mm total length and would thus be one or two year old fish. Rainbow trout growth appeared to be appreciably faster in the middle section of the Swan River than in the upper section (Table 9).

Juvenile bull trout grew relatively slowly in tributary streams but growth accelerated rapidly after these fish emigrated from tributary streams, primarily as one and two year old fish (Table 9). Bull troutwerethe most long-lived trout species in the drainage and were alsothelargest. Fish longer than 700 mm total length were not uncommon in spawning runs. However age and growth information on these fish was difficult to obtain because of scale regeneration and problems with age determination on older fish. Growth and condition of Swan Lake bull trout was better than that reported for nearby Flathead Lake by Leathe and Graham (1982).

Direct empirical information on the growth of repeat-spawning bull trout in the Goat Creek drainage was obtained via the recapture of 31 repeat spawners during the fall of 1984 that had been

Table 9. Age and growth information for four trout species in various portions of the Swan River drainage.

Area	Species		Total length (mm) at age I	II	III	IV	V	VI	VII	VIII	IX	X
Tributary streams	Cutthroat	Length (mm) (n)	47 (339)	(302) 83	(173) [illegible]	151 (45)	176 (3)					
Tributary streams	Juvenile bull trout	Length (mm) (n)	59 (278)	103 (122)	144 (21)							
Lake, river and tributaries	Bull trout (adult & juvenile)	Length (mm) (n)	66 (551)	127 (395)	221 (293)	330 (266)	424 (183)	510 (96)	602 (36)	662 (9)	689 (2)	704 (1)
River (upper section)	Rainbow	Length (mm) (n)	74 (64)	137 (8)	192 (4)	224 (1)						
River (middle section)	Rainbow	Length (mm) (n)	82 (244)	153 (96)	258 (39)	351 (17)	425 (7)					
River (middle section)	Brook trout	Length (mm) (n)	95 (185)	162 (53)	193 (2)							

tagged during the fall of 1983. Recaptured fish weresegregated into100 mm sizegroups based on their initial length to account for size-related growth differences. As shown in Table 10, most repeat spawning bull trout grew nearly SO mm during the period between spawning. This was somewhat surprising since these fish typically left the spawning streams during October in poor condition and migrated approximately 27 km (17 miles) downstream to Swan Lake where they would reside untilupstream spawningmovements were initiated the next May through July.

Movement

Cutthroat Trout

A total of 1,320 cutthroat trout were tagged in tributary streams during three field seasons (1982 - 1984). Only three of these tags were returned by anglers and all these fish were captured in the same stream where they were tagged. The few fish recaptured by MDFWP electrofishing crews were also collected in their source stream.

Only four suspected migratory adult cutthroat trout were captured in fish traps set in Hall, Groom, Bond, Lost and Soup Creeks during the spring and early summer of 1983. All these fish were captured in downstream traps, suggesting that they had completed spawning and were returning to downstream areas. Only 21 juvenile cutthroat were captured (all in downstream trap) in spite of the fact that moderate to high densities of cutthroat trout were known to exist in accessible areas upstream from trap sites. Trap catches of emigrating juvenile cutthroat trout were typically high throughout the spring and early summer period in Flathead River tributaries that supported migratory cutthroat runs (Montana Fish and Game 1979, Graham et al. 1980).

Instream movements of cutthroat trout in a proposed small hydro project area on upper Soup Creek were evaluated by electrofishing 14 established sections in April and November of 1983 and in May of 1984 using previously described methods. A total of 216 cutthroat trout100 mm and longer were captured in the re-survey of the 14 sections during November of 1983. Fifty-one of these fish had been tagged in April and 88% of these previously tagged fish were recaptured in the same 30 m section in which they were tagged. Only six fish were recaptured away from their "home" section. One of these moved upstream one section, four moved down one section and one fish moved nine sections (about one kilometer) downstream.

During the May 1984 re-survey of upper Soup Creek a total of 31 previously tagged fish were captured. Twenty-two of these had been tagged the previous November and nine had been tagged in April, 1983. All of the November fish and eight of the nine April recaptures were captured in their home section during May of 1984. One fish moved downstream one section (110 meters) during the

Table 10. Average growth increments (millimeters, total length) for migratory adult bull trout tagged after spawning in the Goat Creek drainage during the fall of 1983 and recaptured following repeat spawning in fall, 1984.

Length when tagged (mm)	No. of fish recaptured	Ave. growth (TL, mm)	Standard deviation (mm)
301-400	1	110	---
401-500	4	48	(±22)
501-600	12	SO	(±14)
601-700	9	49	(±14)
701-800	5	2s	(±11)

period April 1983 through May 1984. Only one tagged cutthroat was captured in a trap fished at the downstream end of the study area on upper Soup Creek during the spring and early summer of 1983. The results of our cutthroat trout movement studies indicate that the tributary streams studied supported primarily resident fish and received little use by migratory cutthroat trout for spawning and rearing. Movements of these resident fish were generally small, on the order of 100 meters or less. Our findings were similar to those of Miller (1957) who reported a home territory of not more than 20 yards for cutthroat trout in Gorge Creek, Alberta. Loss of Floy fingerling tags in our study was four percent between April and November of 1983.

Brook Trout

A total of 10 and 432 brook trout were tagged in the Swan River and its tributaries, respectively during the study period. Eighty-four percent of the tributary fish were tagged in movement sections established in lower Soup Creek. Six brook trout tags were returned from fish that were tagged in Soup Creek and subsequently recaptured in the same area by anglers. One fish tagged in the Swan River during August of 1982 was caught by an angler in Soup Creek in October of 1982. This fish moved about 8 km down the Swan River prior to entering Soup Creek where it may have spawned.

Only eight of the 14 movement sections established in lower Soup Creek during April of 1983 to monitor brook trout movements were resurveyed during November due to problems with ice buildup. Only 11 of the 232 brook trout larger than 100 mm captured during November had been tagged the previous April. Eight of the 11 recaptured fish were found in their home section while three had moved either two or three sections (220 to 330 m) downstream. From these investigations we concluded that brook trout generally remained in their home streams and moved little.

Bull Trout

Approximately 550 juvenile bull trout were tagged in tributary streams during the study period. A few of these fish were recaptured in their home stream by MDFWP electrofishing crews and two such returns were obtained from anglers. Only one juvenile bull trout displayed a significant movement; it was tagged in Goat Creek in August of 1982 and recaptured by an angler in Swan Lake (27 km downstream from Goat Creek) in January, 1984.

A total of 270 post-spawning adult (larger than 400 mm) bull trout were tagged in fall trapping operations conducted on Goat Creek. As of December of 1984, tags from 24 of these fish were returned by anglers. Eighteen of these returns came from fish caught in Swan Lake and four of these were recaptured within 17 days of tagging, indicating a rapid return to the lake following spawning. Five fish that had been tagged in the fall of 1983 were subsequently caught in the Swan River in the vicinity of Goat Creek during the summer of 1984. These fish were likely returning up the river system to spawn again.

Only one tagged adult bull trout was recaptured outside of the Swan River drainage, indicating that the Swan population was essentially isolated, probably because of the previously mentioned hydroelectric diversion dam on the Swan River immediately above Flathead Lake. This 804 mm long fish was tagged at Goat Creek in September of 1983 and migrated 64 km downstream to Flathead Lake and then 55 km up the Flathead River to where it was caught in June, 1984. The timing of this 119 km (74 mile) movement suggested that the fish may have been bound for a spawning area in the upper Flathead River system. Tag loss for repeat spawning bull trout at Goat Creek was estimated to be 31 percent.

Bull Trout Spawning Surveys

Redd Counts

Ground survey crews censused 76 to 211 km of potential bull trout spawning habitat in tributary streams during the years 1982 through 1984 (Appendix A-2) and located 206 to 327 redds each year (Table 11). Ninety percent or more of all bull trout spawning each year occurred in approximately 29 km (18 miles) of habitat located in four tributary streams (Elk, Lion, Goat, and Squeezer creeks). Bull trout were very selective in choosing spawning areas as there were about 340 km (211 miles) of accessible stream habitat in the Swan tributary system. The most concentrated spawning use in the drainage occurred each year in Elk Creek, where 44 to 52 redds were found in the most heavily used one-kilometer section.

Over the three-year period, an average of 84% of bull trout redds were found in low gradient (0 to 3%) stream reaches in medium or large sized drainages while only one percent were found in reaches having gradients higher than six percent. Between 16 and 20% of all redds found each year were located within proposed small hydro project diversion areas (Table 11). This represented a serious threat to migratory bull trout production in the drainage since these fish spawn in the fall and the eggs incubate during the winter months when dewatering for power production would most likely occur. Bull trout redd distribution graphs and spawning maps may be found in Leathe et al. (1985b).

Characteristics and Size of Spawning Runs

Numbers of bull trout redds observed in Swan tributaries were similar to counts made in the Middle Fork of the Flathead River drainage (300 and 237 redds during 1980 and 1981, respectively) by Fraley et al. (1981) and Shepard et al. (1982). Based on redd

Table 11. Number of bull trout redds found in tributaries to the Swan River during 1982 through 1984. Numbers of redds found within diversion areas of proposed small hydro projects are in parenthesis. Asterisks indicate that the creek was not surveyed.

Creek	Number of redds 1982	1983	1984
Cedar	1	*	*
Cold	1(1)	9(8)	6(3)
Elk	56	91	93
Glacier	0	1	*
Goat	33 (16)	39 (16)	31 (20)
Jim	*	7	6
Lion	63 (4)	49 (4)	88 (13)
N. Fork Lost	9(8)	6(6)	7(5)
S. Fork Lost	2(1)	1(1)	12 (3)
Piper	0	0	1(1)
Squeezer	41 (11)	57 (7)	83 (17)
Woodward	0	1	*
S. Woodward	0	2	*
Lost	0	0	0
Total	206 (41)	263 (42)	327 (62)

count information, spawner densities in Swan Lake appeared to be substantially higher than those in Flathead Lake or Pend Oreille Lake, Idaho (Table 12). Both of the latter two lakes support popular recreational bull trout fisheries.

Length frequency diagrams for post-spawning migratory adult bull trout captured in trapping operations on Coat Creek (including Squeezer Creek, its major tributary) indicated a relatively even size distribution of spawners, ranging between 350 and 830 mm total length (Figure 7). Age frequency analysis indicated thatmostfish in the run were between four and seven years of age (Table 13) but this analysis may have been biased towards younger fish since suitable scales for age determination were difficult to obtain from the larger, older fish.

Returns from trapped fish (adjusted for tag loss) indicated that 33% of the 1984 run was comprised of repeat spawners from 1983. It was estimated that most spawning during 1984 was completed by mid-September since 84% of the identifiable spent females had moved through the trap by that time. Emigration of males peaked during the following week. Trapping results were not used to estimate total run size in either year because traps were not installed until spawning (and probably some emigration) had commenced. Experience from such operations in other parts of the Flathead drainageindicatedthat traps often disrupted upstream spawning movements.

CREEL CENSUS

Swan Lake

Anglers expended 21,734 hours (±2540 hours; 95% CI) of fishing effort on Swan Lake between May 21, 1983 and May 18, 1984. This pressure estimate was based on 411counts of anglers made on 231 days of the 365 day fishing season. Using an average of 3.17 hours per completed trip, a total of 7093 angler-days was estimated. Ninety-four percent of total fishing pressure was expended in the southern half of the lake and 83% of total pressure was attributed to boat anglers. Seventy-two percent of total annual fishing pressure occurred during the four summer months, May through August (Figure 8). The ice fishing season (January through March) accounted for 11% of total annual pressure.

Kokanee salmon were the most numerous species harvested from Swan Lake by anglers during the year and an estimated 14,430 fish averaging 240 mm total length were taken (Table 14). Ninety-seven percent of the kokanee harvest occurred during the months of June through September. The average catch rate for the 156 parties interviewed who fished specifically for kokanee was 1.68 fish per hour.

Table 12. Population density estimates for migratory adult bull trout based on annual redd count data in the Swan Lake, Flathead Lake, and Pend Oreille Lake systems.

Drainage	Year	Estimated number of adults [a]	Surface area of lake (hectares)	Adults per hectare
Swan	1982	800 [b]	1,085	0.74
	1983	1,000		0.92
	1984	1,250		1.15
Flathead [c]	1980	2,400	51,000	0.05
	1981	2,500		0.05
	1982	4,700		0.09
Pend Oreille [d]	1983	3,125 [b]	38,300	0.08

a/ Assuming spawning escapement of 3.2 fish per redd (Fraley et al. 1981).

b/ Swan and Pend Oreille estimates assume 3.2 fish per redd and 80% redd counting efficiency (Fraley et al. 1981).

c/ Data from Fraley et al. (1981), Shepard et al. (1982), Shepard and Graham (1983c).

d/ Data from Pratt (1984b).

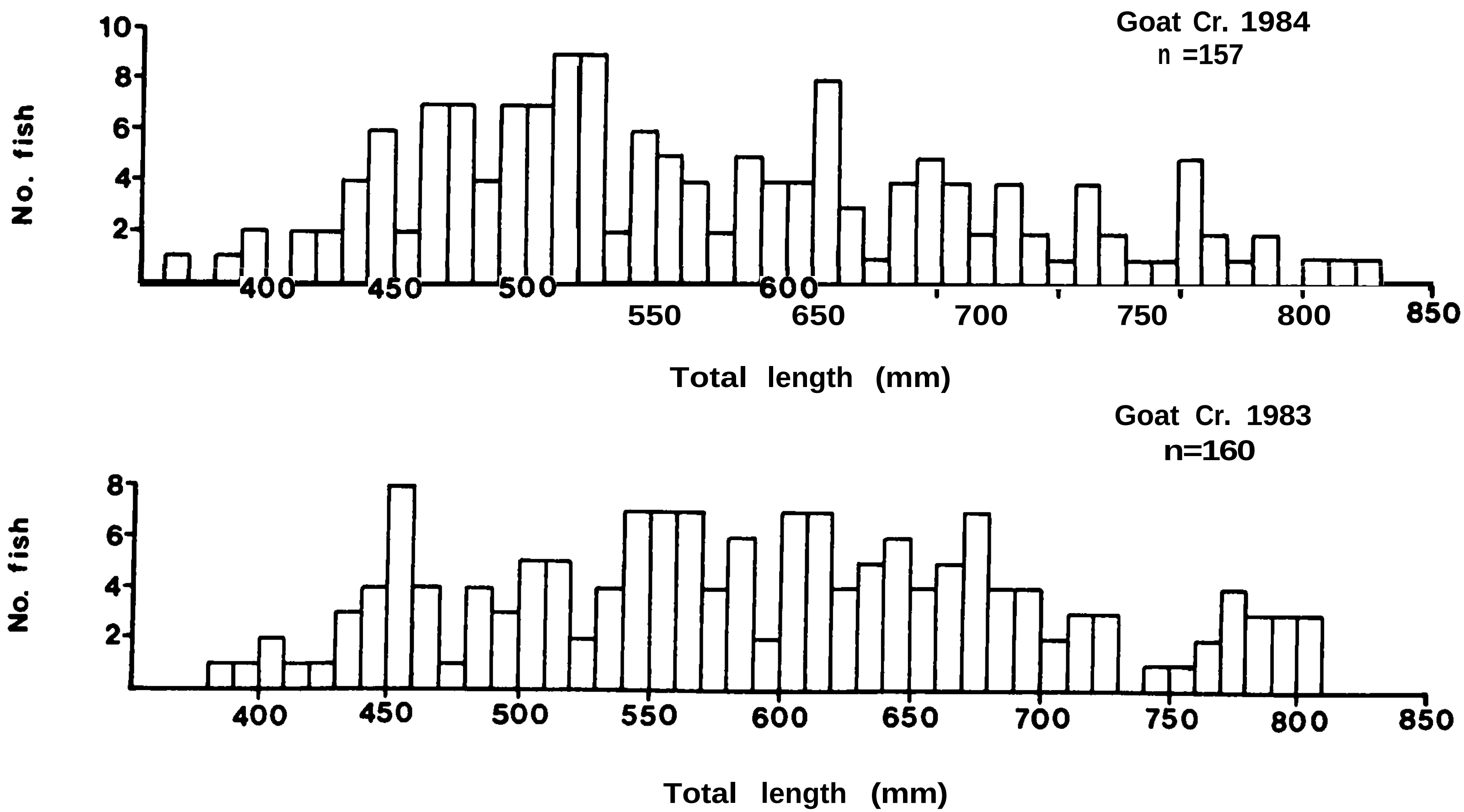

Figure 7. Length frequency diagrams for migratory adult bull trout captured in trapping operations at the mouth of Goat Creek in the Swan River drainage during the fall of 1983 and 1984.

Table 13. Age distribution of post-spawning migratory adult bull trout captured in trapping operations at the mouth of Goat Creek in the Swan River drainage during the fall of 1983 and 1984.

Age (years)	1983 run No. of fish	(%)	1984 run No. of fish	(%)
3	0	(0)	0	(0)
4	14	(20)	19	(20)
5	19	(26)	33	(34)
6	20	(28)	28	(29)
7	13	(18)	13	(14)
8	5	(7)	2	(2)
9	1	(1)	0	(0)
10	0	(0)	1	(1)
Total	72		96	

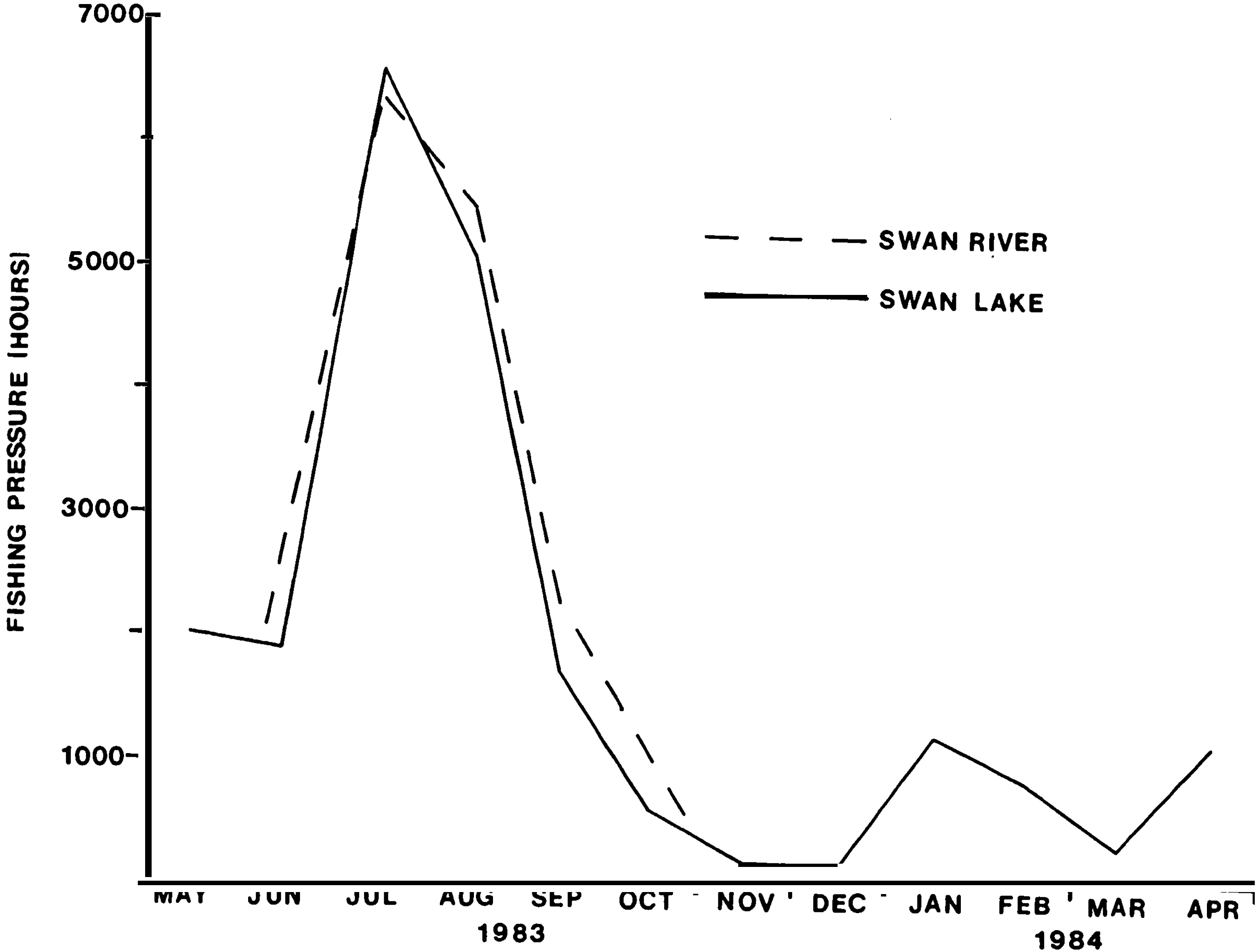

Figure 8. Monthly distribution of fishing pressure (angler-hours) in Swan Lake and Swan River during 1983 and 1984.

Table 14. Harvest estimates (with 95 percent confidence intervals) and length information for the five principal gamefish species caught in Swan Lake during 1983 and 1984.

Species	Estimated harvest (±95% CI)	Average length (mm)	Length range (mm)	Number of fish measured
Kokanee salmon	14,430 (±3,392)	240	192-309	57
Northern pike	1,238 (±461)	613	392-891	65
Bull trout	739 (±263)	458	298-708	69
Rainbow trout	284 (±182)	292	243-328	6
Cutthroat trout	238 (±147)	296	259-352	5

Anglers harvested an estimated 1238 northern pike from Swan Lakethataveraged 613 mm long (Table 14). All of the estimated pike harvest occurred during the months of April through October and no pike fishing parties were encountered during the period November through March. The average catch rate for the 100 interviewed parties who fished specifically for pike was 0.21 fish per hour.

Bull Trout were the third most abundant fish species harvested from Swan lake and creeled fish averaged 458 mm long (Table 14). The total harvest of 739 fish was distributed relatively evenly across all months of the year. Bull trout were sought by 92% of 154 ice fishing parties interviewed during the late fall and winter months (November through March). However, harvest was not particularly high during these months because overall fishing pressure was low incomparisonto other months (Figure 8). Bull trout anglers experienced an average catch rate of 0.26 fish per hour for the entire season and winter catch rates were usually 0.28 to 0.32 fish per hour. These anglers releaseda much larger percentage of their catch (65%) than did northern pike or kokanee anglers (3% and 4%, respectively). Many bull trout anglers were cognizant of the life history of the species and voluntarily released subadult fish in spite of the fact that the bull trout limit in effect was 10 pounds and one fish, or 10 fish.

On an annual basis, 69% of interviewed Swan Lake fishing parties originated from the three local counties (Lake, Flathead, and Missoula) while 20% were residents of other states and Canada. Nonresident and Canadian anglers comprised 33 to 45% of the parties interviewed during June, July and August, indicating the significance of summer tourism in the Swan drainage.

Distinct seasonal fisheries existed for thethreeprincipal gamefish species harvested from Swan Lake. Similar types of specific fisheries were identified in nearby Flathead Lake by Graham and Fredenberg (1983). Seventy-three percent of the 593 parties interviewed during the one-year study on Swan Lake reported that they fished specifically for either kokanee salmon, northern pike, or bull trout.

An estimate of fishing pressure directed specifically at each of the three main target species was obtained on a monthly basis by multiplying monthly pressure estimates by the percent of all parties interviewed during the month that fished for a particular species. For example, during August of 1983, a total of 103 fishing parties were interviewed, 48% of which reported fishing specifically for kokanee. It was then assumed that 48% of the 5067 hours expended during August were directed exclusively at kokanee, which amounted to 2432 hours. Using this approach, we estimated that 7079, 4112, and 3558 hours were spent fishing specifically for kokanee salmcn, northern pike, and bull trout respectively. These numbers probably underestimated total pressure on these species since portions of multi-species fishing trips were likely devoted to them as well. Comprehensive tabular summaries of Swan Lake creel results are in Leathe et al. (1985a).

Swan River

An estimated 16,508 (±2742; 95% CI) hours were expended by anglers fishing three sections of the Swan River during 1983 (Table 15). This estimate was derived from aerial counts made on 101 days of the 194 day fishing season. Using an average of 2.76 hours per completed trip, atotalof 5981 angler-days were estimated. Monthly fishing pressure estimates for the Swan River were very similar to corresponding estimates for Swan Lake (Figure 8). Most (71%) of the total river fishing pressure occurred during July and August and fishing pressure was greatest in the section immediately above Swan Lake (Table 15). Boat fishing was negligible in the upper two sections but comprised 36% of the total fishing pressure estimated for the lower section (Leathe 1985).

Using interview information from 248 parties of anglers and fishing pressure estimates, we estimated that 2399 brook trout and 1765 rainbow trout were harvested from the Swan River during 1983 (Table 16). Lesser numbers of bull trout (564), cutthroat trout (240), and mountain whitefish (11) were taken. Bull trout up to 697 mm in length were caught (Table 16) and length frequency data indicated that 44% of the bull trout catch was comprised of adult fish (larger than 400 mm). As would be expected, catch rates for brook and rainbow trout (0.33 and 0.27 fish per hour) were much greater than those for bull and cutthroat trout (0.06 and 0.05).

Interview results indicated that Swan River anglers were far less particular in terms of fish species sought than were Swan Lake anglers. Seventy-two percent of the River fishing parties reported fishing for trout in general or "any fish". Six percent of the parties interviewed fished specifically for bull trout while 13%, 6%, and 3% fished for rainbow, brook, and cutthroat trout respectively. Most parties (71%) were from the three local counties (Flathead, Missoula, and Lake) while 22% were from out-of-state and only one percent were Canadian. Swan River creel census results are also in Leathe et al. (1985a).

Tributaries

As discussed in the Methods section of this report, two different methods were used to indirectly estimate tributary fishing pressure. Based on the relative number of completed trip hours censused at check stations, we estimated that tributary fishing pressure was about 61% of Swan River fishing pressure. Responses to the 1982-1983 statewide mail survey of anglers indicated that tributary pressure was 44% of Swan Lake fishing pressure. Applying these percentages to our river and lake pressure estimates yielded tributary fishing pressure estimates of 10,136 and 9573 hours. It

Table 15. Fishing pressure summary for three sections of the Swan River during 1983. Ninety-five percent confidence intervals are in parenthesis.

Secticn	Section length (river km)	Fishing pressure (hours; ±95% CI)
Swan L. to Goat Cr.	30	8,113 (±2,203)
Goat Cr. to Cold Cr.	24	4,218 (±1,114)
Cold Cr. to Cygnet L.	31	4,197 (±1,193)
Total	85	16,507 (±2,742)

Table 16. Estimated harvest (±95% confidence interval) and size information for gamefish fran three sections of the Swan River during 1983.

Species	Estimated harvest (±95% CI)	Average length (mm)	Length range (mm)	Number of fish measured
Brook trout	2,399 (±1,004)	218	160-287	26
Rainbow trout	1,765 (±674)	264	163-440	38
Bull trout	564 (±264)	444	220-697	9
Cutthroat trout	240 (±153)	226	192-285	4
Mountain whitefish	11 (±20)	---	---	--

was encouraging to find that these independently obtained estimates were very similar to one another. We chose to use theaverage of the two (9850 hours) as our best estimate of total tributary fishing pressure during the1983 fishing season. Using an average of 3.04 hours per completed tributary fishing trip, this equated to 3,240 angler-days.

Creel clerks interviewed 50 fishing parties that had fished on at least 17 different tributaries within the study area during 1983. Most (47%) of the parties fished specifically for brook trout while 49% fished for trout in general or "any fish" and 4% fished for cutthroat trout. No tributary fishing parties reported fishing exclusively for bull trout. Eighty-six percent of the parties were from the three local counties and another 12% were out-of-state residents or Canadians.

Brook trout comprised almost all (91%) of the tributary harvest (Table 17). The estimated harvest of 9653 fish was more than four times the harvest estimated for the entire Swan River even though estimated tributary fishing pressure was only 60% of river pressure. Results of the tributary creel survey are in Leathe et al. (1985a).

HYDROLOGY AND INSTREAM FLOW NEEDS

Suitable flow records for the water year October 1, 1983 through September 30, 1984 were obtained for five creeks (Piper, Cold, Soup, Lion, and Squeezer) where small hydro sites were proposed. Problems with calibration and operation of the gage on the South Fork of Lost Creek precluded detailed hydrologic analysis for this stream. Piper Creek was chosen as an example for this discussion since it's hydrologic characteristics were intermediate and, in many respects, representative of the other sites where detailed measurements were made. Detailed information for the other sites may be found in Leathe et al. (1985a).

Streamflows in Swan tributaries are greatest during the early summer months and depend on the amount and rate of snowmelt in these mountainous watersheds (Figure 9). For four of the gaged streams, 74-75% of total annual water yield for the 1983-84 water year occurred during the four months of April through July. Flow responses were slightly delayed and moderated in the fifth stream (Cold Creek) where 68% of total annual water yield occurred during the four months of May through August. Although not quantified, available evidence suggested that streamflows in the Swan drainage during the 1983-84 water year were fairly typical (if not somewhat low) in comparison to most years.

A single inflection point at 9.0 cubic feet per second (cfs) was identified on a composite wetted perimeter versus discharge curve for three riffle-run cross sections on upper Piper Creek (Figure 10). This was selected as the recommended minimum flow by

Table 17. Catch rate, size, and estimated total harvest of the four fish species caught in tributaries in the Swan River drainage at or above Swan Lake during 1983.

Species	**Estimated harvest** [a/]	**Catch rate** [b/] **(fish/hr.)**	Average length **(mm)**	Length range **(mm)**	Number of fish measured
Brook trout	9,653	1.53	207	115-405	11
Rainbow trout	394	0.05	133	133-133	2
Cutthroat trout	2%	0.07	189	150-219	3
Bull trout	296	0.07	172	135-214	6

[a/] Harvest estimate derived using 9850 hours of fishing pressure.

[b/] Includes fish that were subsequently released.

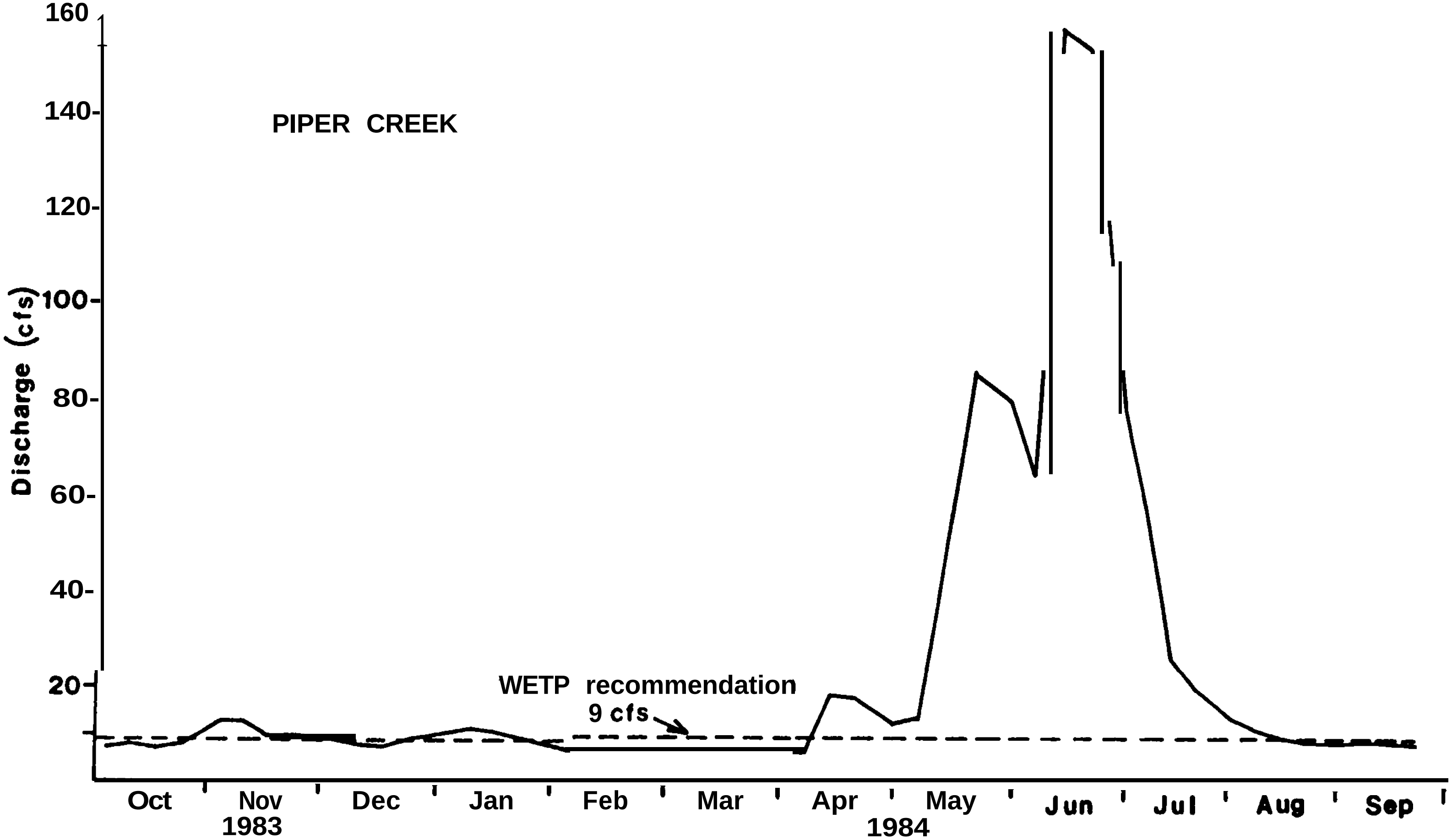

Figure 9. Average weekly discharge at a gaging point in upper Piper Creek in the Swan River drainage during the period October 1983 through September 1984.

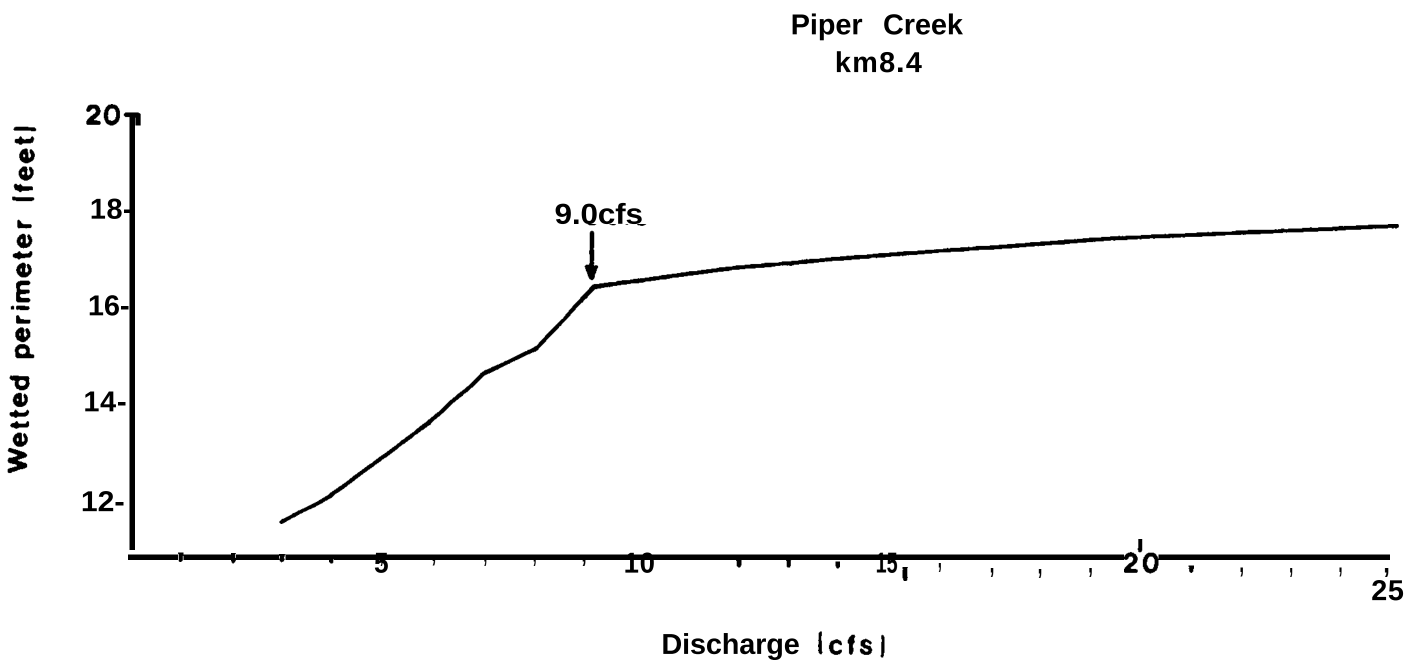

Figure 10. The relationship between average wetted perimeter and discharge for three cross sections on upper Piper Creek during 1982. A single inflection point at 9.0 cubic feet per second was the recommended minimum flow.

all three resource management agencies involved (MDFWP, USFS< and U.S. Fish and Wildlife Service) since losses in wetted perimeter (amount of wetted stream bottom) accelerated rapidly as flow was reduced below 9 cfs. Thewettedperimeter technique for identifying recommended minimum streamflows is predicted on the concept that as wetted perimeter drops below an optimal level (defined by an inflection point or points), the ability of the stream to support desirable levels of trout abundance is diminished (Nelson 1984). Reduction of wetted perimeter in riffle areas is believed to index losses in food production area, bank cover, spawning area and fry rearing habitat.

Nelson (1980) concluded that the wetted perimeter method provided acceptable absolute minimum flow recommendations for five reaches on “blue ribbon" trout rivers in Southwestern Montana for which long-term trout population and discharge data were available. However, further investigation will be required to determine the validity of this technique for determining recommended minimum flows for small high-gradient mountain streams where micro-hydro projects are typically proposed.

For reasons of simplicity and enforceability, a single year-round minimum flow was selected for each proposed project. Since the projects would not divert a significant portion of runoff flows, separate "high-flow recommendations" to provide normal flushing and channel maintenance functions were judged unnecessary. Complex seasonal recommendations or recommendations developed for different flow years (i.e. drought, normal, and high flow years) were considered counterproductive because they might be difficult for operators to follow and would be more difficult to enforce.

A conflict arose between prospective small hydro developers and resource management agencies regarding water availability because most streams in Montana's mountainous watersheds are typically at base flow conditions during most months of the year (Figure 9). Minimum instream flow recommendations for Swan tributaries usually amounted to the 56th to 76th percentile flows (Table 18; Figure ll), meaning that excess water would be available for other purposes for 56 to 76% of the time. In one extreme case (Squeezer Creek) excess water would only be available for 36% of the year. Prospective hydro developers protested that instream flow requests were inordinately excessive and often exceeded the amount of water normally flowing during the low flow period (Figure 9). The economics of project development dictated that power production (and concomitant seasonal dewatering of diversion zones) would have to occur on a year-round basis in order for the operations to be profitable.

Resource management agencies generally selected a relatively high (upper inflection point) minimum flow recommendation because fishery resource values in most cases proved to be high. Many of the project areas supported populations of westslope cutthroat trout (a species of "special concern' in Montana) or provided

Table 18. Comparison of recommended minimum flow with mean annual flaw and percentile flows for five gaged tributary streams in the Swan River drainage.

Creek	Mean annual flow (cfs)	Recommended minimum flow (cfs)[a]	Percent of mean annual flow	Percentile flow
Cold	46.6	23.0	49%	65
Lion	58.9	15.0	25%	76
Piper	23.5	9.0	38%	56
Soup	10.4	4.0	38%	60
Squeezer	20.4	11.0	54%	36

[a] Based on wetted perimeter measurements.

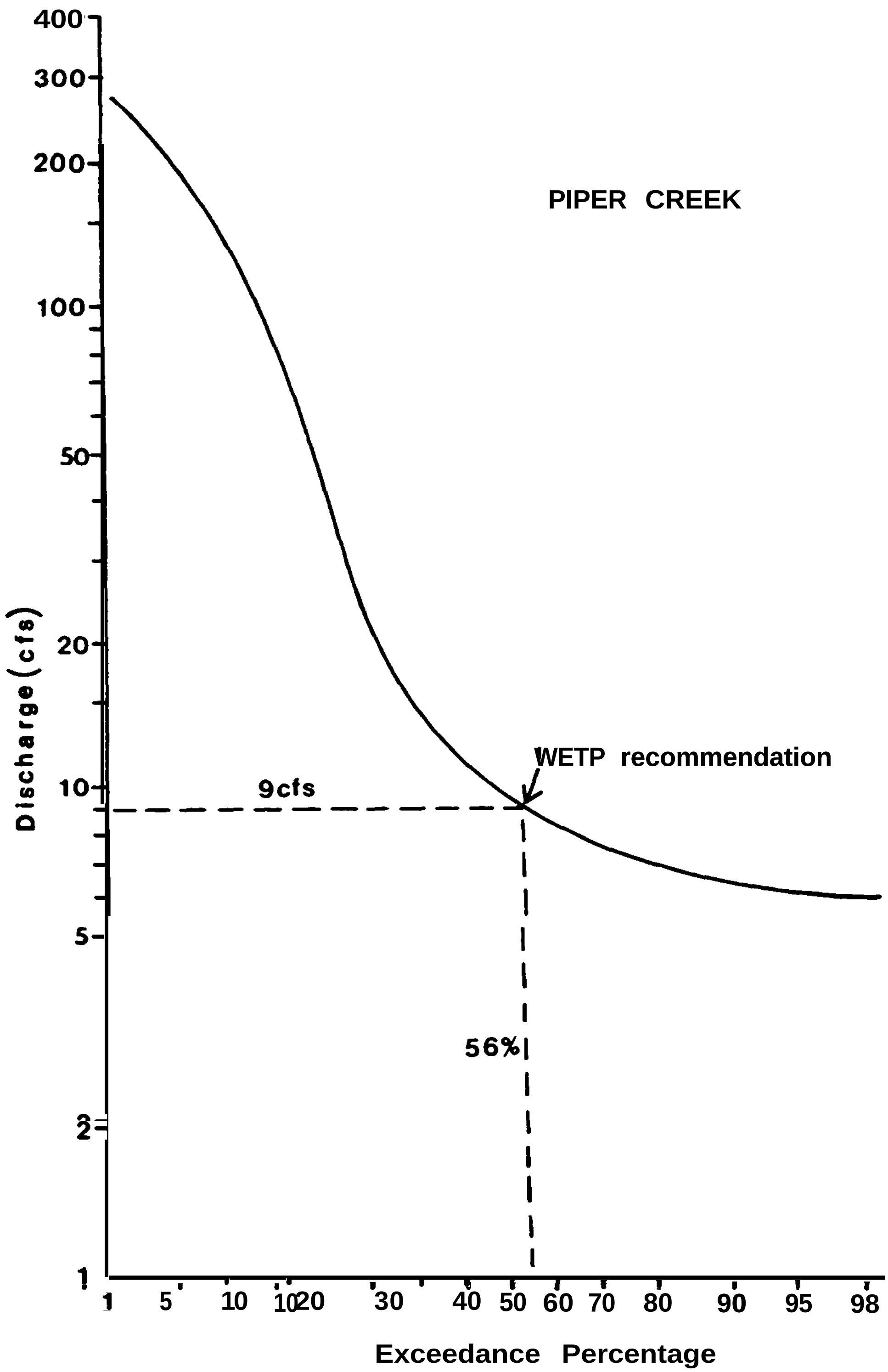

Figure 11. Flow duration at a gaging point on upper Piper Creek in the Swan River drainage during the period October 1983 through September 1984.

spawning and rearing habitat for migratory bull trout. Had the resourcevalues been lower, lower minimum flow recommendations could have been justified.

Recommended minimum flows for the five gaged Swan tributaries were compared to hydrologic data to determine if suitable minimum flow recommendations could be made based only on available hydrologic information. The results of these comparisons were mixed and indicate that only preliminary estimates could be made in lieu of field measurements. On the average, recommended minimum flows amounted to about 41% of mean annual flow but this factor varied between 25 and 54% (Table 18). Recommended minimum flows were approximated by the 58th percentile flow on average, however the range was wide (36 to 76 percentile; Table 18). The ommission of the Squeezer Creek data resulted in an average minimum flow recommendation that corresponded to the 64th percentile flow.

The conflict over water availability in mountain streams during the low flow period (particularly the winter months) prompted the MDFWP to conduct a review of available literature concerning winter conditions and trout habitat requirements in small mountain streams in order to develop a policy concerning winter flow depletions. This review exposed an urgent need for more information and also identified winter streamflow and related habitat conditions as a critical factor that regulates trout populations in these streams (Montana Department of Fish, Wildlife and Parks 1984a). Available evidence indicates thatsubstantialand even catastrophic flow fluctuations often occur naturally in mountain streams during the winter months due to the accumlation and subsequent dispersal of anchor ice, resulting in sequential flooding and dewatering of stream channels (Maciolek and Needham 1952, Reimers 1957, Needham and Jones 1959, and Butler 1979). These sudden changes can cause substantial mortality to fish and other aquatic life by stranding, freezing, and crushing or suffocation from collapsing snow and ice.

Because it was concluded that winter dewatering for power production would only aggravate existing harsh conditions, the MDFWP adopted a policy in November of 1984 that prohibits water withdrawal from Montana's unregulated mountain streams during the winter months (November through March). This policy (Montana Department of Fish, Wildlife and Parks 1984b) is to remain in effect until research information proves otherwise, and it does not apply to:

1) Regulated streams

2) Streams with no fish populations or without recreational potential, and

3) Streams with marginal fish populations where adverse impacts can be mitigated.

SEDIMENTANALYSIS

Existing Situation

Natural sediment loads estimated for individual reaches of Swan River tributaries were roughly proportional to drainage basin size and varied from 24 to 7764 tons per year. Road construction and maintenance accounted for the majority of man-induced sediment loads to streams. In 1983, roads produced an estimated 0.2 to 223.2 tons of sediment in study reaches, representing an increase of 0 to 114% over natural sediment loads. Sediment related to clearcutting was estimated at 1.1 to 397.1 tons for 1983, or 0 to 48% over natural sediment. Stowell et al. (1983) reported increases in sediment yields up to 375% over natural levels for Idaho watersheds that had been roaded and logged.

Sediment loads from roads and logging expressed separately as percent increases over natural levels for individual reach basins were significantly ($p<0.05$) related to streambed fines (Table 19) and substrate score (Table 20). However, when sediment increases from roads and logging were used as separate independent variables in a multiple regression along with stream gradient, logging-related sediment became non-significant ($p>0.05$) in explaining streambed variability (Tables 19 and 20). Also, total sediment increases due to roads and logging were less closely correlated with streambed condition than was road sediment alone. Therefore, the significance of logging sediment is probably due to an indirect relationship: timber harvests are associated with road construction. All other variables tested were either nonsignificant (numbers 1 through 5 on page 30) or did not produce higher correlation coefficients.

Other studies have also found roads to be the major source of sediment produced during timber harvesting (Fredricksen 1970, Megahan and Kidd 1972, Rice et al. 1972, Anderson et al. 1976). The estimation of sediment produced from roads is relatively straightforward. Sediment associated with logging, however, is much more difficult to estimate because assumptions must be made regarding shape of cutting units, density of roads and skidtrails, location of log landing sites, type of yarding equipment used, treatment of slash, and fireline requirements. For the most part, ground disturbed during timber harvest revegetates quickly. Mass soil movements caused by changes in soil hydrology and loss of root cohesion after tree removal have been reported in other regions (Swanston 1970, Swanston 1974, De Graff 1979) but are not common in the Swan basin.

In a final attempt to develop a significant multiple regression component for logging-related sediment, coefficients were revised to model ground disturbance from skidtrails only. Skidtrails can function as temporary extensions of the road system and are likely to be the most important source of sediment during

Table 19. Regression parameters for relationships between streambed fine sediment (0-6.4 mm) levels and various environmental variables for tributaries in the Swan River drainage.

Dependent variable	Independent variable(s)	Significance	Slope	Intercept	Coefficient of determination
Percent fines	Percent increase sediment over natural due to roads in reach basin	p=0.000	0.84	14.33	0.50
Percent fines	Percent increase sediment over natural due to logging in reach basin	p=0.000	0.81	18.76	0.24
Percent fines	Stream gradient	p=0.001	-1.98	33.39	0.22
Percent fines	Percent increase sediment over natural due to roads in reach basin	p=0.000	0.72	21.84	0.58
	Percent increase sediment over natural due to logging in reach basin	p=0.814	0.05		
	Stream gradient	p=0.013	-1.18		
Percent fines	Percent increase sediment over natural due to roads in reach basin	p=0.000	0.74	21.99	0.58
	Stream gradient	p=0.009	-1.21		
Percent fines	Percent increase sediment over natural due to made — reach basin plus routed upstream sediment	p=0.000	0.59	30.66	0.42
	Stream gradient	p=0.000	-2.13		

Table 20. Regression parmeters for relationships between streambed substrate score and various environmental variables for tributaries in the Swan River drainage.

Dependent variable	Independent variable(s)	Significance	Slope	Intercept	Coefficient of determination
Substrate score	Percent increase sediment over natural due to roads in reach basin	$p=0.000$	-0.09	13.06	0.50
Substrate score	Percent increase sediment over natural due to logging in reach basin	$p=0.000$	-0.09	12.61	0.25
Substrate score	Stream gradient	$p=0.000$	0.24	10.86	0.28
Substrate score	Percent increase sediment over natural due to roads in reach basin	$p=0.000$	-0.08	12.07	0.61
	Percent increase sediment over natural due to logging in reach basin	$p=0.781$	-0.01		
	Stream gradient	$p=0.002$	0.16		
Substrate score	Percent increase sediment over natural due to roads in reach basin	$p=0.000$	-0.08	12.05	0.61
	Stream gradient	$p=0.001$	0.16		
Substrate score	Percent increase sediment over natural due to roads — reach basin plus routed upstream sediment	$p=0.000$	-0.07	11.17	0.50
	Stream gradient	$p=0.000$	0.26		

timber harvesting. However, this refinement of the logging sediment analysis failed to produce any significant results.

When natural and man-induced sediment loads from upstream reaches were added directly to the totals for each reach, the relationship between sediment increases and streambed condition weakened. Furthermore, as a separate variable in regression analyses, increased upstream sediment itself was not significant ($p>0.05$). Although upstream sediment loading would be expected to affect downstream habitats, the dynamics of sediment routing become more complex with greater distance from the source. A multitude of morphologic and hydrologic variables affect the rate and quantity of sediment delivery to downstream reaches (Dietrich et al. 1982).

The technique for routing sediment described by Cline et al. (1981) did not require site-specific data and provided an alternate means of incorporating upstream sediment in the regression analysis. Results given in Tables 19 and 20 show that percent sediment increases which include a routed portion of natural and road-related sediment from upstream reaches were significantly ($p<0.05$) related to streambed condition. Coefficients of determination were somewhat lower than those for regressions using only individual reach basin sediment.

Gradient of the reach itself was a significant ($p<0.05$) variable in all regressions of percent sediment increase over natural with streambed condition (Tables 19 and 20). Logarithmic transformation of stream gradient improved the fit of regression equations. This was not unexpected since changes in channel gradient have a large influence on sediment transport at low gradients but become less important at higher gradients. Final equations used for sediment modeling are given on page 74.

It is interesting that sediment loads expressed as a percent increase over natural levels showed the strongest relationship with streambed condition. The results suggest that most sediment from natural erosion is transported out of these streams. According to Megahan (1979), sediment transport capacities of low-order mountain streams in undisturbed watersheds tend to exceed sediment supplies. Development can potentially increase sediment loads to levels which exceed stream flushing capacities. At this point, deposited sediment would begin to degrade stream substrates and impair fish production.

Potential Sources of Model Error

A substantial amount of variation in streambed composition among reaches cannot be explained by our regression models. The best-fit regression produced an R^2 value of 0.61 (Table 20), leaving 39% of the substrate score variation unaccounted for. Although coefficients of determination were relatively high for these simple watershed models, likely error sources should be mentioned.

Hydrologically-important factors that were omitted from the analysis constitute a source of "external" error. Annual precipitation rates as well as episodic events, i.e., storms and floods, have major influences on sediment-transport processes but are difficult to incorporate into watershed models (Cederholm et al. 1980, Megahan 1981, Kelsey 1982, Lehre 1982, Swanson et al. 1982b). We did not attempt to model these effects. Likewise, we were not able to specifically quantify in-channel sediment storage capacity, which varies widely among stream reaches and plays a major role in sediment dynamics (Lehre 1982, Madej 1982, Megahan 1982). And finally, the technique for routing sediment to downstream reaches was chosen for its simplicity and provides only a coarse approximation of a complex process.

Technical mistakes and violations of assumptions used in estimating sediment yields can be considered "internal" model errors. Landtype-based sediment models are vulnerable to mapping error and aredependenton the use of average erosion rates. Within landtypes, natural variation in erosional processes and instance of mass wasting can produce considerably more (or less) sediment than predicted. Although landtypes are distributed around stream channels in a characteristic pattern, the actual distances from specific parcels of land to a stream channel vary greatly, both within a landtype unit and between units of the same landtype. This results in different sediment delivery efficiencies which are not accounted for in the model.

Coefficients for estimating road-related sediment are also subject to error from limited sensitivity to stream proximity. These coefficients represent average rates of erosion from typical road construction and maintenance activities; the unique aspects of individual projects are not considered. Furthermore, each road segment must be assigned a specific year of construction to determine its recovery status, despite the factthata section of road may require more than one year to complete. Additional error may stem from the averaging of sediment produced over estimated maintenance cycles for collector roads. Sediment yields during the year after a major maintenance project would be much higher than the average value.

Prediction of Future Impacts

Because they enabled us to best evaluate downstream cumulative effects of development, the following regression equations were chosen to predict changes in stream substrate conditions in the study reaches:

percent fines = $34.18 + 0.55(X_1) - 24.80(X_2)$ $R^2=0.49$
(0-6.4 mm)

substrate score = $10.81 - 0.06(X_1) + 2.91(X_2)$ $R^2=0.56$

where X_1 = percent increase in sediment over natural levels, and $X_2 = \log_{10}$ stream gradient.

These relationships are depicted for four example stream gradients in Figures 12 and 13.

Expected sediment increases due to road development as well as micro-hydro development were evaluated. Sediment from upstream reaches was included using the Cline et al. (1981) routing technique. Sediment from clearcutting was not predicted because of the non-significance of logging sediment in multiple regressions.

IMPACT EVALUATION CRITERIA

One objective of this project was to develop guidelines and criteria that could be used to evaluate the potential resident fishery impacts that may result from the construction and operation of micro-hydro projects in small mountain streams. The successful completion of this objective would require that field measurements be made at one or more hydro projects during construction and operation so that appropriate inferences could be made. Since no projects were constructed in the study area during the period of investigation, our ability to collect on-site monitoring information was limited. Consequently, rather than identifying specific guidelines and criteria, the following discussion describes what were judged to be the most important factors to be considered in evaluating the impacts of small hydrodevelopment, the relative importance of these factors in the Swan drainage, and how they were addressed in the cumulative effects analysis. When possible, potential guidelines and evaluation criteria are presented along with supporting references.

Fish Species and Life History

The species composition, life history, and population density of fish communities in areas influenced by small hydro projects are primary factors to be considered in impact analysis. Bull trout were chosen as the principal species of concern in this study because of their migratory nature (dependence upon tributary streams for spawning and rearing and on Swan Lake for growth to maturity), their ability to attain trophy size (in excess of 30 inches total length), their importancetothe Swan Lake and Swan River fisheries, and their substantial use of project streams. Cur results indicated that more than 60% of the entire population of juvenile bull trout in the tributary system were found either within or downstream from proposed small hydro projects.

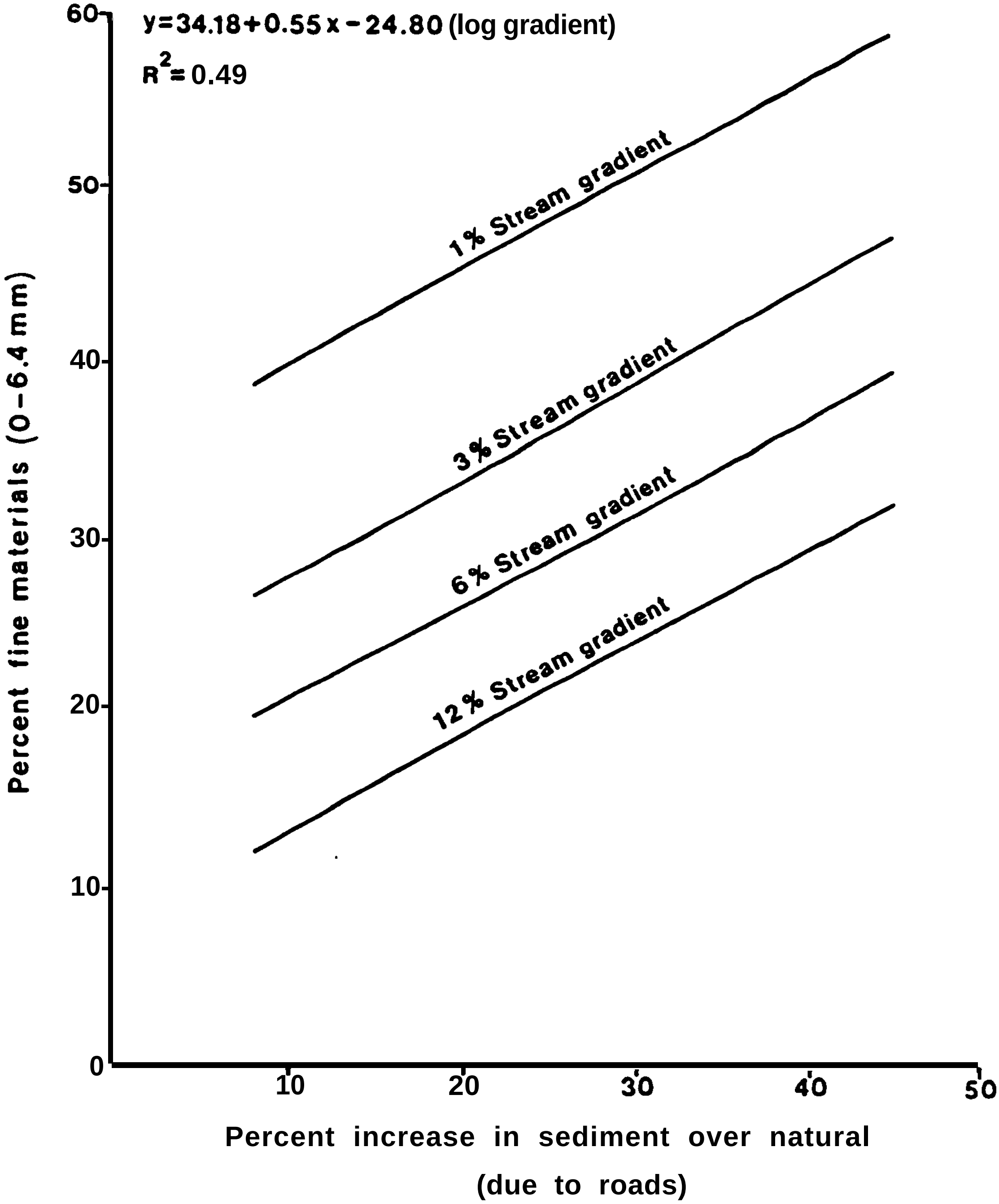

Figure 12. The relationship betwen percent fine materials (0 to 6.4 mm) in streambeds and sediment loading rates (percent over natural levels) resulting fran road construction and maintenance in Swan tributary drainages.

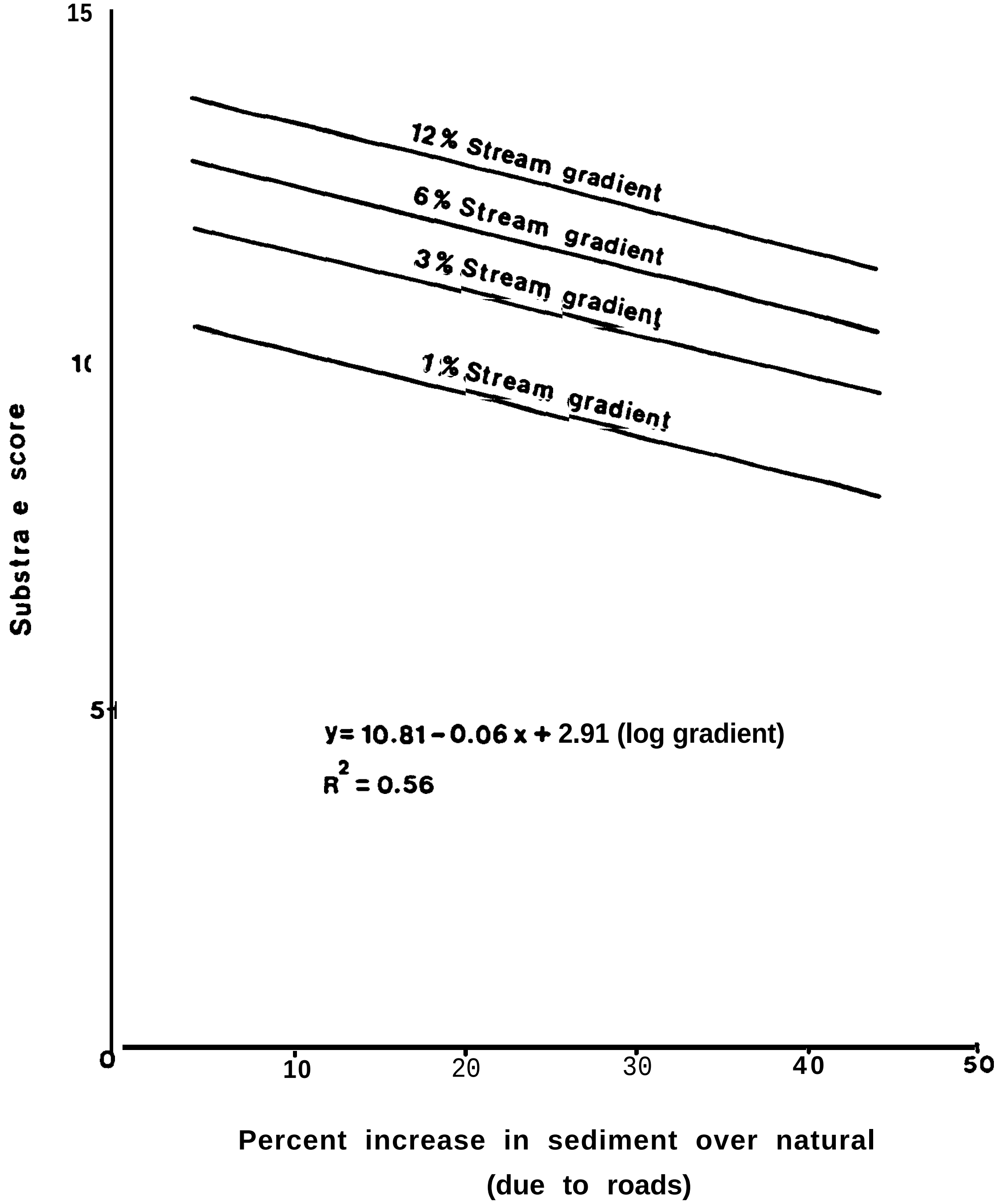

Figure 13. The relationship between streambed substrate score and sediment loading rates (percent over natural levels) resulting from road construction and maintenance in Swan tributary drainages.

Westslope cutthroat trout were of less importance in this analysis because of their restrict& distribution in the drainage, lack of significant migratory runs, and small contribution to the sport fishery. However, this species inhabited many of the proposed small hydro diversion areas and was important from a genetic standpointbecauseof its status as a species of special concern in Montana. Electrophoretic analysis of cutthroat from three project streamsthatwere considered likely to support genetically pure westslope cutthroat revealed that two of the streams (Groom and Sixmile creeks) did contain pure populations whereas the cutthroat from the other stream (Soup Creek) had hybridized with introduced Yellowstone cutthroat trout. We suggest that electrophoretic tests be made to identify the genetic makeup of cutthroat trout found in proposed small-hydro project areas where westslope cutthroat trout are suspected to be present and where the preservation of this subspecies is a priority. It was somewhat surprising to find relatively dense cutthroat populations (70 to150 fish 75 mm and longer per 300 meters) in streams having quite steep average channel gradients (17 to 23%).

Brook trout were considered a low priority species in this analysis because of their limited distribution within project areas and their apparent tolerance of heavily sedimented stream reaches. Only about four percent of the total estimated tributary brook trout population was found within proposed diversion areas while about one-third was foundinreachesdownstream fromproposedhydro sites.

Detailed life history information for fish species of interest is needed to fully evaluate the effects of small hydro development. Basic life history patterns (resident versus migratory) will determine the scope of potential impacts since effects on resident species would be more localized than those on migratory species. Timing of spawning, size of spawning fish, and (for migratory species) the size of emigrating smolts and the timing of smolt migration are important life history characteristics.

Dewatering

The potential dewatering of thousands of feet of stream is a critical issue to be addressed when evaluating the impacts of high-head small hydro development on mountain streams. A serious conflict concerning water availability during the low flow period (September through March) was identified during the consultation process for proposed Swan projects. Economic and engineering feasibility studies conducted by the prospective developers indicated that the hydro projects would be profitable only if they could be operated on a year-round basis. In some cases portions of streams would be totally dewatered to facilitate power production, especially during the winter. This was of concern because if all 20 proposed projects were constructed, approximately 100 km of tributary streams (13% of the total tributary system) would be susceptible to dewatering impacts. This would impair carrying capacity for all trout species and also affect the incubation success of fall-spawning brook and bull trout.

Instream flow recommendations derived using the wetted perimeter technique usually amounted to the 56 to 76 percentile flow in Swan tributaries. Consequently, most projects would be able to operate for sixtonine months of the year and would have to shut down during periods when naturally occurring low flows are considered critical to the preservation of aquatic life.

We attempted to develop a general model that could be used to predict the effects of incremental flow reduction on trout populations within proposed diversion areas, using information obtained by Randolf and White (1984) on a trout stream in southwestern Montana. In that study, water levels and rainbow trout populations were manipulated and monitored to determine the relationship between trout population density and changes in wetted perimeter and other habitat variables. Randolf and White (1984) provided general support for the use of the wetted perimeter technique in small streams, although enough variability was observed between experimental stream sections to preclude the development of a meaningful dewatering impact model that could be used in this analysis.

Fish population response to streamflow alterations is likely species specific and dependent on the amount and types of habitat present in each stream section. Consequently, a technique such as IFIM (Instream Flow Incremental Methodology; Bovee 1982) that directly quantifies amounts of fish habitat may be more appropriate for predicting the effects of flow reduction on trout habitat. However, the population responses of target fish species to changes in amounts of suitable habitat need to be quantified.

Our inability to predict fish population responses to incremental dewatering does not appear to seriously affect the validity of this cumulative impact analysis. Consultations with developers have indicated that assumption of total dewatering of diversion zones at some point in time during the low water period is realistic, due to the marginal economics of project development.

Upstream Passage

Measures to provide suitable upstream passage conditions for migratory and resident fish include the provision of adequate passage flows as well as the installation of fishways at diversion sites. Migrating adult bull trout in the Swan drainage utilized proposed diversion reaches having average channel gradients of up to six percent but limited spawning and rearing use by these fish was observed upstream from proposeddiversionpoints. Upstream movements of juvenile bull trout and resident cutthroat and brook trout inhabiting many proposed hydro project areas on Swan tributaries were likely limited by the small size of these fish and the presence of natural hydraulic features. As described previously, cur movement information for residentcutthroattroutinaproposed diversion area on Soup Creek (11% gradient) suggests that net movements were extremely limited, usually on the order of 150 meters or less. Significant seasonal movements were not detected, but may exist in other streams.

Most upstream fish passage facilities for Swan hydro projects would therefore need to be designed to accommodate localized movements of small resident fish. Vertical slot fishways may be best suited to these small streams since they accommodate a wide range of flow conditions without the need for adjustment (British Columbia Ministry of Environment 1980). However, it is difficult to make specific recommendations because no fish ladders have been constructed and evaluated on small streams in northwestern Montana. Design considerations for various fishways are available in a handout published by the National Marine Fisheries Service (undated) and may also be found in Hildebrand (1980).

Downstream Passage and Turbine Mortality

Fish screening devices should be installed at diversion sites where necessary to prevent mortality or injury to juvenile or resident salmonids migrating downstream. Recommended screen mesh size depends on the size of downstream migrating fish. Screen openings of no more than 0.125 inch (3.2 mm) in the narrow direction are recommended for fry (<59 mm total length), whereas openings of 0.25 inch (6.4 mm) are recommended for fingerlings (>60 mm; National Marine Fisheries Service 1982). Screen openings of no more than 0.10 inch (2.5 mm) are specified by the British Columbia Ministry of Environment (1980). Most juvenile migratory westslope cutthroat and bull trout in the Flathead drainage emigrate as one to three year old fingerlings (Fraley et al. 1981), hence screen openings of no more than 0.25 inch (6.4 mm) should prevent entry of these fish into penstocks.

Turbine mortality would likely be very high for fish entrained at small high-head hydro projects since most would use impulse turbines (Pelton wheels) propelled by high speed water jets directed through small diameter high pressure nozzles. Turbine mortality was not consider& to be a potentially serious problem in Swan tributaries since the use of areas upstream of proposed diversions by migratory fish appeared limited and resident fish movements were localized. Criteria describing approach velocities, screen material, screen location, and required amounts of wetted screen are detailed by the National Marine Fisheries Service (1982) and B.C. Ministry of Environment (1980). Various designs for screening facilities are described in the latter publication.

Sediment

The construction of access roads, penstock routes, diversion structures, transmission lines, and powerhouses may result in the addition of significant amounts of fine sediment to streams. Many of these facilities would be constructed in steep terrain either in close proximity to or (in the case of diversion structures) within the stream channel itself. Most projects proposed in the Swan drainage would have buried penstocks which would require the clearing of about a 15 to 20-foot right-of-way for pipe burial. In many cases these right-of-ways would become service roads to maintain and repair diversion structures and penstocks. The potential cumulative effects of sediment production resulting from small hydrodevelopmentwas a primary concern of this study. Detailed descriptions of the problem and how it was evaluated may be found elsewhere in this document.

To reduce sedimentation problems, adequate buffer strips should be maintained between penstock routes, roads, and the stream. Penstock routes should employ existing roadways when possible and disturbed areas should be mulched and revegetated as soon as possible to achieve stabilization. Steep slopes can be covered with woven cloth mesh material to accelerate the revegetation and stabilization process and filtering cloth can be installed in critical areas to intercept fine sediment from runoff water.

The potentially catastrophic effects of penstock rupture and resultant streambed sedimentation could be reduced by the installation of an automatic shutoff device at the diversion point. Diversion structures should also be designed and constructed to automatically pass a guaranteed minimum flow and allow normal stream bedload movement to occur. This would obviate the need for periodic dredging or flushing of accumulated streambed material, which can detrimentally affect aquatic biota. Conceptual designs for diversion structures having these features are presented by Montana Department of Fish, Wildlife and Parks (1984).

Temperature Alterations

Alteration of normal thermal regimes could occur within and below diversion areas as a result of transporting water downslope over considerable distances in a buried pipeline before returning it to the stream. Summer water temperatures within dewatered reaches could be elevated due to decreased flows and water velocity and also because of reduced shading by riparian vegetation. Similarly, winter ice conditions could become more severe in diversion reaches if water is withdrawn for power generation. The winter icing problem would be aggravated by artificial flow fluctuations that result from periodic maintenance, adjustment, and repair of hydro project facilities. Sudden flow increases during winter months could dislodge and transport ice, causing excessive streambed scouring which may affect incubation success of the eggs of fall-spawning fish species (such as bull and brook trout) and overwinter survival of all resident fish. Downstream influences of temperature changes would vary depending upon the season and the proportional amount of water that is diverted. Hydro diversion returns could result in downstream waters that are cooler in the summer and warmer in the winter.

Water temperature comparisons were made at two operating small hydro projects in northwestern Montana during late summer to gain an understanding of the magnitude of temperature change one might expect as a result of project operation. Water temperature alterations were relatively minor at the Addition Creek hydro project where daily maximum water temperatures were often increased during transit through the penstock (Appendix A-3). However, it was subsequently discovered that this phenomenon may have been caused by discharges from a water heater that was installed in the powerhouse to consume excess electricity. This situation did not exist at the Whitefish hydro project, where maximum and minimum daily water temperatures were reduced an average of at least 4.5 and 3.5 degrees Farenheit as a result of diversion through the 12,500 foot penstock (Appendix A-4).

Because of a lack of detailed site-specific monitoring information concerning the effects of small hydro operation on thermal regimes, it was not possible to incorporate this factor in our analysis in a quantitative manner. From a qualitative standpoint however, some inferences can be made using the limited information available. A significant negative relationship (r=-.45) was observed between maximum summer water temperature and juvenile bull trout density in 26 Swan tributary reaches that supported bull trout. This type of relationship has been observed elsewhere (Pratt 1984a) and suggests that cool hydro diversion returns may improve downstream rearing conditions for juvenile bull trout. However, the lack of significant correlations between water temperature and cutthroat and brook trout density suggests that these species would not benefit from cooler water temperatures.

In diversion zones, small increases in water temperatures during the summer as a result of dewatering may be detrimental to juvenile bull trout. Such an increase in diversion zone water temperatures was not observed at the Addition Creek project (Appendix A-3) but may occur at other projects having different aspects, riparian shading, meteorological conditions, diversion lengths, or operational characteristics.

Gas Saturation

The results of limited measurements of total gas saturation made at two small hydro projects operating in northwestern Montana suggest that this is a potential problem warranting further investigation. No evidence of gas supersaturation was found during on-site investigations made at the Addition Creek project during normal operation on 23 August and 28 September, 1984. Similarly, nothing unusual was noted at the Whitefish project on 24 August. However, on 28 September total dissolved gas saturation was 123% immediately below the powerhouse, but only 101% at each of the two diversions.

It was originally believed that the most likely cause of gas supersaturation at high-head small hydro projects would be air leaks into the penstock system or at the turbine in the powerhouse. However, measurements made at the Addition Creek project and on the first occasion at the Whitefish project indicate that this did not normally occur. Conversations with the operator (Jeff Jordan, Hydro Management, Inc.) of the Whitefish hydro project led to the conclusion that the high gas saturation value observed in late September was due to an adjustment in project operation made a few hours prior to the measurement. This adjustment involved reducing the flow of water through the turbine (by reducing nozzle diameter) in order to raise the water level in the penstock and thus increase the effective head. Apparently, air pockets were trapped in the penstock during the filling process and air was driven into solution under pressure as these pockets were carried through the pipeline.

Because the incidence of gas supersaturation appears to be strongly related to project operation, one would expect the problem to vary considerably between projects and on a seasonal basis at a given project. Gas supersaturation would likely be more common at projects located on "flashy" streams where fluctuating hydrographs dictate frequent adjustment of the facility to maintain optimum power production. Similarly, more problems would be expected at projects where design flaws necessitate frequent shut-downs (penstock draining and subsequent refill) to facilitate repairs and maintenance. On a seasonal basis, one would expect fewer problems during high water periods when projects would likely run at a peak capacity at all times and, if designed as the Swan projects were proposed, would divert a relatively small percentage of the streamflow. In that case, supersaturated diversion waters would be diluted appreciably upon return to the stream. The problem would be more severe if it occurred during low water periods when a much larger percentage of the stream would be diverted.

The effects of gas supersaturation on fish are most severe in shallow water (less than one meter in depth) where fish cannot achieve depth compensation to avoid gas bubble disease (Weitkamp and Katz 1980). Because of this fact, Thurston et al. (1979) recommended that total gas pressure not exceed 105% in shallow water areas, less than 60 cm deep. Potential gas supersaturation is a concern when evaluating small hydro projects because most are located on small streams (seldom more than one meter deep) that often support populations of juvenile fish that typically select habitats in shallow water along stream margins. Information from Dawley and Ebel (1975) and Ebel (1973) indicated that 50% mortality of juvenile chinook salmon occurred in 27 and 14 hours in shallow water having 120% and 125% total gas saturation, respectively, while 50% mortality of juvenile steelhead trout occurred in 33 to 114 hours under these same conditions. However, the effects may be mitigated if this exposure is intermittent (Weitkamp and Katz 1980), as it may be below small hydro projects. The installation of boulder splash basins at powerhouse outfalls and careful (possibly automated) operation of projects to minimize water level fluctuations within penstocks could potentially prevent gas supersaturaticnproblems.

CUMULATIVE IMPACT ANALYSIS

The two environmental effects of micro-hydroelectric development that were considered most important to fish in this analysis were dewatering of diversion zones and sedimentation of stream substrates. These, then, were the factors used to predict response of fish populations to various levels of hydroelectric development. Other potential impacts, such as those in the previous discussion, could assume greater importance in other aquatic systems.

Dewatering

Two strategies of power plant operation were modeled. The first strategy provides a minimum instream flow (WETP method) throughout the stream sectionbypassed bytheproposed penstock. Although aquatic productivity would likely decline as a result of the unnatural flow reduction, no significant fish losses were predicted for stream diversion zones. Project operation was not expected to impair stream flushing power, since only a small fraction of peak flow would be diverted.

The second strategy of power plant operation would divert most, if not all, of the streamflow into the penstock during the winter low-flow period. Since there can be no guarantee that enough water would be allowed to bypass the penstock to prevent dehydration or freeze-up of stream diversion zones, complete loss of fish habitat was assumed. And, because juvenile bull trout must overwinter at least one year in rearing areas, these diversion zones were considered lost to bull trout production. Furthermore, these sections could not support resident cutthroat or brook trout during the critical winter period when habitat is considered most limiting to fish populations in small mountain streams (Montana Department of Fish, Wildlife and Parks 1984).

Sediment

Juvenile bull trout densities in the Swan drainage were found to be negatively correlated **($r=-0.57$)** with percent streambed fines (O-6.4 mm) and positively correlated **($r=0.63$;** Figure 14) with substrate score. In both cases, increasing sedimentation is

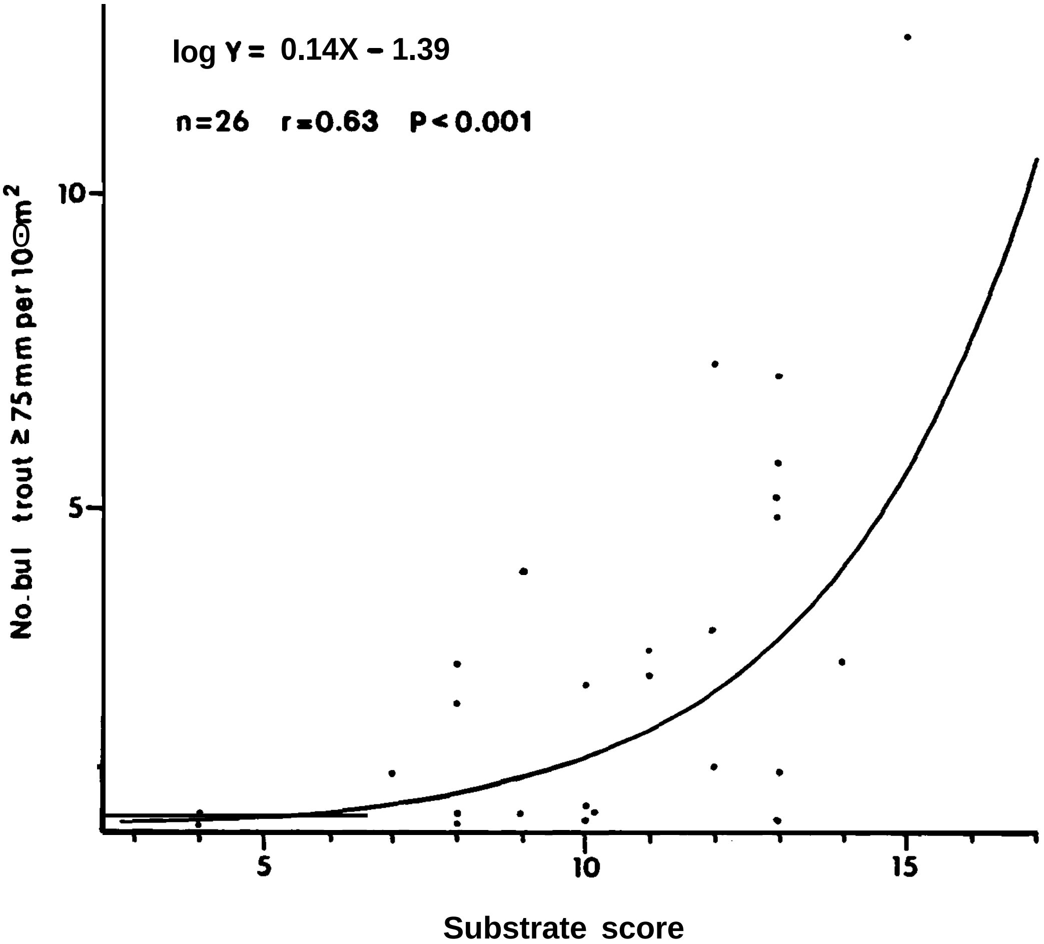

Figure 14. The relationship between average substrate score and juvenile bull trout density (number of fish 75 mm and longer per 100 square meters of stream) for 26 tributary reaches in the Swan River drainage during 1982 and 1983.

associated with decreasing bull trout abundance. As discussed previously, substrate score was the most important variable in a multiple regression model relating juvenile bull trout density to stream habitat characteristics. Others have reported that young bull trout were strongly oriented to the streambed and made extensive use of interstitial spaces in the substrate as hiding cover (Griffith 1979, Oliver 1979, Pratt 1984a). Sedimentation reduces interstitial space, thereby decreasing the quantity and quality of habitat for juvenile bull trout. The detrimental effects of sediment on bull trout spawning success (Shepard etal. in press) may also be a factor in the sediment/bull trout relationship.

Since the substratescore regressions provided a better fit than the percent fines regressions, they were used to model the effect of future development on bull trout populations. Increased sediment production due to road and hydroelectric development was predicted for 1987 through 1991, as previously described. Individual micro-hydro projects and multiple development scenarios were modeled for their effect on substrate scores in bull trout rearing reaches. Then, bull trout densities in affected streams were predicted using the equation in Figure 14. Finally, population estimates were made for all reaches supporting migratory bull trout by multiplying predicted fish densities by reach areas.

These results were compared with "baseline" bull trout populations, that is, the theoretical potential of the streams in an undeveloped state to produce bull trout. Baseline juvenilebull trout populations in each rearing reach were estimated by first assuming no increase over natural sediment in the equation from Figure 13. Resulting substrate scores were used in the equation from Figure 14 to predict bull trout densities.

In the following discussions, it should be remembered that sediment effects were predicted using a regression equation that accounts for about 40% of the observed variation in juvenile bull trout abundance. Obviously, there are other factors regulating this fish population, such as annual flow conditions, number of spawning adults, migration barriers, and predation. However, stream substrate quality is likely to be the habitat component (other than flow) which is most significantly altered by develop ment of these watersheds.

Neither cutthroat nor brook trout populations in Swan River tributaries showed a significant negative relationship with stream-&d sedimentation. Other studies, however, have documented many detrimental effects of sediment on stream salmonids (Reiser and Bjornn 1979). The limited distribution of westslope cutthroat in the Swan drainage may have precluded our ability to detect a negative response to sediment. Cutthroat trout were largely restricted to high gradient, coarse-bottom stream reaches where other limiting factors may have overshadowed sediment in importance (e.g., winter severity, drought frequency, and cover). Brook trout, on the other hand, appeared to be sediment-tolerant and flourished in low gradient stream reaches where fine materials tend to accumulate in the substrate. Consequently, the effects of development-related sediment increases on cutthroat and brook trout populations were not modeled for this analysis.

Individual Projects

Effect on Bull Trout

Predicted losses of juvenile bull trout production due to forest and micro-hydroelectric development are shown in Table 21. Only those proposed projects which would affect migratory bull trout rearing streams are listed. These losses are expressed as a percentage of potential ("baseline") bull trout production under pristine (undeveloped) conditions. The main purpose of Table 21 is to compare impacts among projects, but losses cannot always be summed to estimate the cumulative impacts of several projects. This is because some projects affect the same bull trout rearing areas and, if constructed, would share portions of their access roads and transmission line corridors. Therefore, sediment impacts on bull trout would be less than the sum of individual project losses. Estimated losses for the following two groups of projects cannot be considered additive: Bethal/Goat/Scout and South Woodward/South Woodward tributary. The cumulative effect of multiple project development is more thoroughly analysed in a later section.

Each hydro project must be evaluated in the context of concurrent development in the same drainage. Combined sediment increases from hydro development and roadconstruction for timber harvest could cause unacceptable damage to individual stream fisheries. Since the greatest impact is expected to occur the first year after project construction, five possible construction years (1986-1990) were simulated and losses estimated for the following year in each case. Although total trout loss did vary depending on year of construction, differences were small enough to justify averaging the five first-year losses for the purpose of comparing projects.

In the left half of Table 21, the percent loss of juvenile bull trout in streams affected by each project is shown. These figures are useful for evaluating the impact of micro-hydro development on individual stream populations of bull trout. Both strategies of power plant operation – instream flow maintenance and total dewatering – were modeled. Loss due to all development is shown as well as that portion due to micro-hydro development alone. With recommendedinstream flows maintained, mostofthe projects by themselves would result in losses of less than five percent of affected bull trout populations. Piper Creek would experience the greatest loss at about ten percent. However, with additional sediment from planned forest development, estimated bull

Table 21. Cumulative percentage loss of potential juvenile bull trout production due to forest and microhydroelectric development (average year-after losses for five possible construction years: 1986-1990). First number given is loss due to all development; number in parenthesis is loss attributable solely to hydroproject developnent.

Project stream	Percentage loss in affected streams: With IFR[a] in diversion zone	Percentage loss in affected streams: Dewatered diversion zone	Percentage loss of Swan drainage production: With IFR[a] in diversion zone	Percentage loss of Swan drainage production: dewatered diversion zone
Bethal	11.6 (2.9)	11.6 (2.9)	0.9 (0.2)	0.9 (0.2)
Cold	21.0 (9.2)	76.0 (64.2)	2.2 (1.0)	8.0 (6.8)
Goat	10.8 (2.1)	45.1 (36.4)	0.9 (0.2)	3.7 (3.0)
Lion	7.7 (3.7)	13.6 (9.6)	1.3 (0.6)	2.3 (1.6)
N.F. Lost	9.2 (2.9)	56.9 (50.6)	0.7 (0.2)	3.5 (3.0)
Piper	22.4 (10.5)	84.2 (72.3)	1.5 (0.7)	5.6 (4.8)
Scout	11.3 (2.6)	11.3 (2.6)	0.9 (0.2)	0.9 (0.2)
S.F. Lost	11.0 (3.0)	42.3 (34.3)	1.1 (0.3)	4.3 (3.5)
S. Woodward	21.8 (9.4)	24.1 (11.7)	1.7 (0.7)	1.9 (0.9)
S. Woodward trib.	14.2 (1.8)	14.2 (1.8)	1.1 (0.1)	1.1 (0.1)
Squeezer	7.6 (2.3)	37.0 (31.7)	0.5 (0.1)	2.4 (2.0)

[a] IFR = instream flow recommendation.

trout losses would range up to 22% in Piper Creek and exceed ten percent in most of the other project drainages.

If diversion zones were dewatered as proposed, significant amounts of bull trout rearing habitat would be affected. Losses would increase dramatically for all but three of the eleven projects listed in Table 21. Bethal, Scout, and South Woodward tributary projects would not dewater bull trout rearing areas. With dewatering, hydro development could result in the loss of 72% of potential bull trout production in Piper Creek and 64% of potential production in Cold Creek, two important rearing tributaries in the Swan drainage. When sediment from other development (road construction) is considered, predicted losses increase to 84% in Piper and 76% in Cold Creek.

The relative importance of each project stream to the Swan bull trout fishery is indicated in the right half of Table 21. Here, losses are expressed as a percentage of the total migratory bull trout production in the Swan drainage. If instream flows are maintained through diversion zones, no hydro project by itself would cause more than a one percent loss of the Swan bull trout fishery. Even with additional sediment from forest development, the greatest loss predicted for a project stream, Cold Creek, would amount to only about two percent of the total Swan drainage population.

However, with dewatered diversion zones, project-related impacts would become more significant. Up to about seven percent of the Swan production of bull trout would be lost due to the Cold Creek project alone, with eight percent lost altogether because of other road construction in Cold Creek basin. Other projects would individually cause losses of from 0.1 to 4.8% of the migratory bull trout fishery, with total losses ranging from 0.9 to 5.6% when forest development is included.

It is obvious that dewatering of diversion zones would have a more serious effect on bull trout than would sedimentation. Furthermore, sediment-related losses displayed in Table 21 should progressively decrease as ground disturbed by construction activities revegetates and sediment delivery to streams diminishes. Annual dewatering, on the other hand, would result in a permanent loss of bull trout habitat, the effect of which can be estimated by subtracting column 2 from 4 and column 6 from 8 for each project in Table 21. Resulting bull trout losses for individual projects would range up to 62% in affected streams and up to 6% of Swan production.

Effect on Cutthroat and Brook Trout

For cutthroat and brook trout, only the effects of diversion zone dewatering were modeled. Existing populations would not be expected to survive winter dehydration or freeze-up of these areas. Losses based on 1983-84 population estimates are given in Table 22

Table 22. Percentage loss of cutthroat and brook trout in the Swan River drainage as a result of total dewatering of the diversion zones of proposed micro-hydro projects.

Project Stream	Percentage loss in project streams		Percentage loss in Swan drainage	
	cutthroat trout	Brook trout	Cutthroat trout	Brook trout
Bethal	0	0	0	0
Bond	12.7	2.5	0.5	0
Cedar	56.1	0	5:o	0
Cold	0	5.8	0.1	0.1
Goat	0	0	0	0
Groom	45.8	0	1.7	0
Hall	26.1	16.2	1.2	0.2
Lime	20.0	0	0.3	0
Lion	0	0	0	0
N.F. Lost	35.4	0	2.1	0
Piper	36.8	45.4	2.1	1.6
Porcupine	0	50.0	0	0.7
scout	0	0	0	0
Sixmile	20.0	0	0.8	0
Soup	90.5	5.9	2.4	0.5
S.F. Lost	34.1	23.3	0.5	0.2
S. Woodward	0	7.4	0.3	0.2
S. Woodward trib.	0	0		0
Squeezer	0	6.2	8.1	0.2
Yew	59.1	0	0.4	0

for all 20 proposed projects. Percentage loss of individual stream fisheries would be substantial in many cases: up to 90% for cutthroat trout in Soup Creek and up to 50% for brook trout in Porcupine Creek. Single project impacts would be less significant in terms of the entire Swan tributary system. Losses would range up to 5% for cutthroat trout and 2% for brook trout.

Multiple Projects

Cumulative effects of forest and micro-hydro development were analyzed for the six multiple-project scenarios described earlier. In these hypothetical scenarios, construction of hydroprojects would begin in 1986 and culminate by 1990 (see development rates in Table 4). Impacts on fish populations would first occur in 1987 and peak by 1991.

Effect on Bull Trout

As in the previous analysis, both instream flow and dewatering operational strategies were evaluated for their effect on juvenile bull trout populations. Estimated losses (Tables 23 and 24) are expressed as percentages of the total potential production of migratory bull trout in the Swan drainage. This provides a standard basis for comparing various levels of development and evaluating significance of their effects on the fishery.

The effects of road construction for planned forest develop ment are shown separately in Tables 23 and 24 but must be added to each scenario's losses to estimate total cumulative impacts. Timing of hydroproject construction and subsequent recovery of disturbed areas was accounted for and integrated with forest development in the computerized sediment model. The full impact of an "incremental" scenario is not felt until after all designated projects are built. In "immediate" scenarios, however, all designated projects are built in 1986 and the greatest impact occurs the next year – 1987.

With the maintenance of recommended instream flows in diversion zones, increased sediment from project construction was the only factor predicted to affect juvenile bull trout populations. **Losses** associated with forest development were estimated at six to seven percent for 1987 through 1991 (Table 23). (Using the same techniques, populations were estimated to be 6% below potential in 1984 due to forest development.) Additional bull trout losses due to hydro- development would not exceed two percent under any scenario except during 1987 for "moderate immediate" and 1987-88 for "full immediate" (Table 23). The greatest impact would occur during 1987 under the "full immediate" scenario (all20 projects constructed) when 10% of the potential

Table 23. Percentage loss of total juvenilebull trout production in the Swan drainage due to forest development and various levels of microhydroelectric development, with recommended minimum flows in diversion zones. See Tables 4 and 5 for complete description of development scenarios. Construction is assumed to begin in 1986 under all scenarios. Losses due to micro-hydro are in addition to those due to forest development.

Scenario	No. projects developed	Impact years 1987	1988	1989	1990	1991
Forest development	0	6.0	5.9	6.3	6.7	7.0
Low incremental	4	0.2	0.8	0.4	1.2	0.8
Low immediate	4	1.8	1.1	0.6	0.6	0.3
Moderate incremental	10	0.8	1.5	0.8	1.3	1.1
Moderate immediate	10	2.7	1.7	0.8	0.8	0.4
Full incremental	20	1.8	1.9	1.2	2.0	1.7
Full immediate	20	4.4	2.7	1.3	1.3	0.6

Table 24. Percentage loss of **total juvenile bull trout** production in the Swan drainage due to forest development and various levels of microhydroelectric development, with dewatered diversion zones. See Tables 4 and 5 for complete descriptions of development scenarios. Construction is assumed to begin in 1986 under all scenarios. Losses due to micro-hydro are in addition to those due to forest development.

Scenario	No. projects developed	Impact years 1987	1988	1989	1990	1991
Forest development	0	6.0	5.9	6.3	6.7	7.0
Low incremental	4	2.1	6.8	6.4	13.3	13.2
Low immediate	4	13.6	13.4	13.0	13.2	13.1
Moderate incremental	10	6.8	13.6	13.0	14.0	14.0
Moderate immediate	10	14.7	14.2	13.5	13.6	13.4
Full incremental	20	13.6	14.4	13.8	18.4	24.3
Full immediate	20	26.1	25.2	24.0	24.2	23.5

bull trout production would be lost, with 4% of this loss due to hydroelectric development.

Multiple-project development would have a much more significant impact on the migratory bull trout fishery if diversion zones were dewatered as is probable (Table 24). And, since dewatering of rearing areas has more serious consequences than does sediment production, the phasing in of multiple projects offers only temporary advantages over all-at-once construction. Eventually, both "incremental" and "immediate" scenarios for the same level of development would result in similar fish losses.

Without minimum flow maintenance, even a "low incremental" scenario (four projects developed, one each year) would ultimately result in the loss of about 13% of juvenile bull trout production, with an additional 7% loss due to forest development. This represents a very significant cumulative loss of 20%, the majority of which would be permanent. Dull trout losses were relatively high for a low level of micro-hydro development because three of the four projects to be built would involve bull trout rearing streams. These projects were ranked high due to developer interest, and it is likely that good winter flow conditions made the streams attractive for hydropower sites as well as optimal for rearing bull trout.

A moderate level of hydroelectric development (ten projects) would ultimately result in only a slightly greater loss of bull trout than would a low level (four projects). The difference in impact between the two levels is minor because only two of the six projects added under moderate scenarios affect bull trout populations. It should be pointed out, however, that predicted fish losses for low and moderate development levels are largely dependent on the choice of projects, which in this study, was made by the ranking process displayed in Table 5. Impacts would vary if different sets of projects were selected for these scenarios.

As expected, construction of all 20 proposed micro-hydroelectric projects (full development) with subsequent dewatering of diversion zones would cause substantial damage to the migratory bull trout fishery of the Swan drainage. Up to 26% of potential juvenile bull trout production would be lost, depending on the rate of development. With the additional impact of forest development, over 30% of the bull trout production would be lost.

The impacts of all three levels of small hydro development on migratory bull trout are summarized in Figure 15. Losses attributed to each of three factors (diversion zone dewatering, sediment from project construction, and sediment from forest development) are shown. Dewatering was responsible for the majority of predicted loss, and as a result, the ultimate impacts of immediate and incremental scenarios were very similar for a given level of development. However, incremental development would result in less impact from hydro-related sediment than would

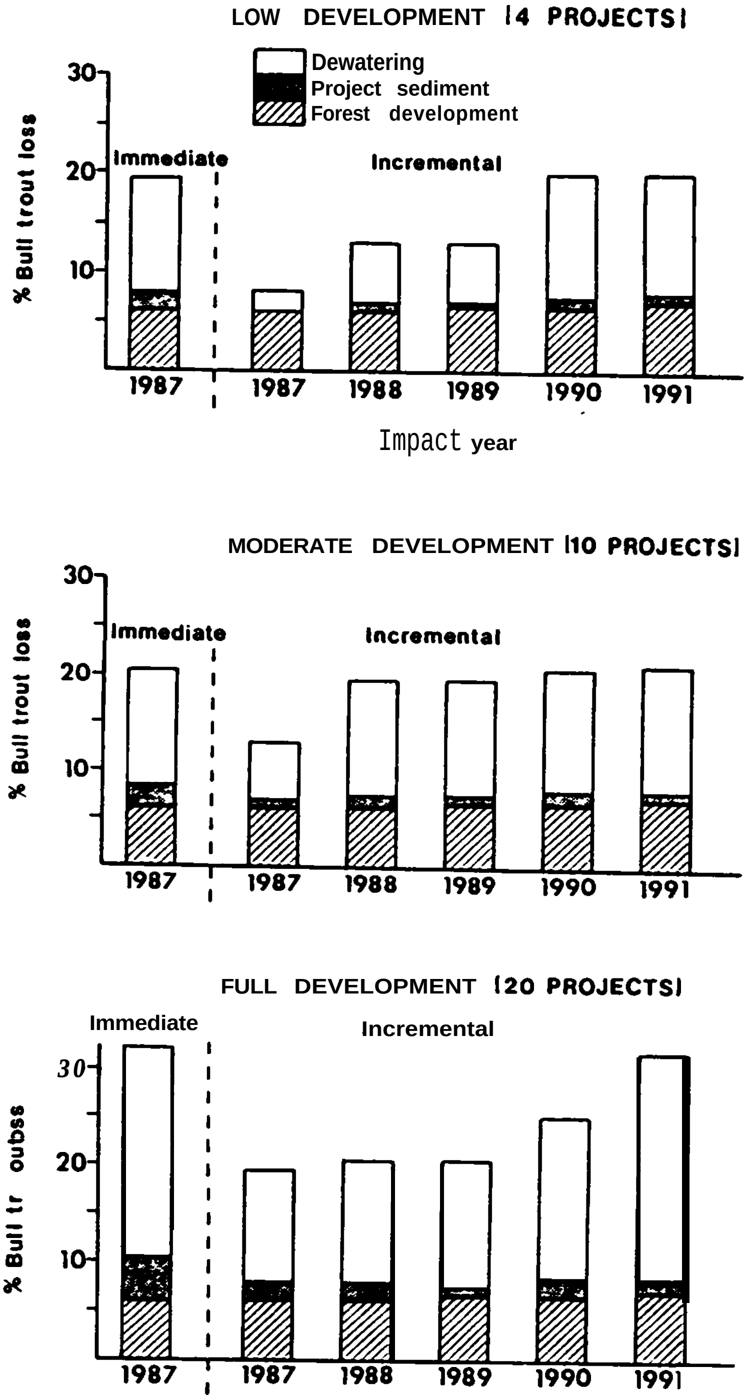

Figure 15. predicted losses in potential migratory bull trout production in the Swan River drainage due to forest development and three levels of small hydro development. Effects of immediate (all projects built in one year) and incremental (construction phased over five years) scenarios are shown for each level of development.

immediate development. Therefore, phased construction should be considered in more sediment-sensitive areas or where dewatering effects are less significant.

Effect on Cutthroat and Brook Trout

Diversion zone dewatering was the only factor used in this analysis to predict the effects of small hydro development on resident cutthroat and brook trout. Without year-round instream flow protection, these zones could not contribute to annual trout production. Fish losses were based on 1983-84 population estimates for each stream section to be bypassed by a micro-hydro penstock. Once all designated projects have been constructed, "incremental" and "immediate" scenarios have identical impact for the same level of development.

Because they were often present in high gradient stream reaches along proposed penstock routes, cutthroat trout would be significantly affected by hydroelectric diversions (Table 25). An estimated 7% of the cutthroat trout population in Swan River tributaries wouldbelostwith a low level of hydro-development (four projects). Under "moderate" scenarios (ten projects), about 12% of the total population would be lost, and under "full" scenarios (20 projects), about 18% would perish.

Brook trout were not as common as cutthroat in proposed diversion zones. The bulk of the brook trout population in Swan River tributaries was found in low gradient reaches downstream from potential hydro sites and in other (non-project) streams. Estimated impact on this species was small, ranging from 2% of the tributary population lost with a low level of micro-hydro development to 4% lost with full development (Table 26).

ECONOMICVALUATION

Travel-cost results placed the net economic value of the Swan River drainage sport fishery at $788,000 per year. This sum was comprised of $455,000, $265,000 and $68,000 for the Swan River, Swan Lake, and tributary fisheries respectively. Dividing the total net value by the 16,300 angler days estimated for the 1983-84 fishing season yielded an average value of $48.30 per angler-day. Average angler-day values ranged between $21.00 for tributary anglers to $76.00 for river anglers.

We did not collect information on actual expenditures (money spent on bait, tackle, travel, lodging, food, and licenses etc.). However, gross expenditures are not considered reliable estimators of resource value (Gordon etal.1973, Palm and Malvestuto 1983, EC0 Northwest 1984). Palm and Malvestuto (1983) found that consumer surplus exceeded actual expenditures by a factor of 1.1 to 1.5 for the sport fishery in a southern reservoir. This factor was

Table 25. Percentage loss of cutthroat trout in tributaries to the Swan drainage due solely to dewatering impacts from various levels of micro-hydroelectric development. See Tables 4 and 5 for complete descriptions of development scenarios. Operation is assumed to begin in 1987 under all scenarios.

Scenario	No. projects developed	Impact Years				
		1987	1988	1989	1990	1991
Low incremental	4	0.1	2.2	7.2	7.3	7.3
Low immediate	4	7.3	7.3	7.3	7.3	7.3
Moderate incremental	10	2.2	7.3	9.3	10.1	11.8
Moderate immediate	10	11.8	11.8	11.8	11.8	11.8
Full incremental	20	7.3	10.1	14.2	14.2	17.5
Full immediate	20	17.5	17.5	17.5	17.5	17.5

Table 26. Percentage loss of brook trout in tributaries to the Swan drainage due solely to dewatering impacts from various levels of micro-hydroelectric development. See Tables 4 and 5 for complete descriptions of development scenarios. Operation is assumed to begin in 1987 under all scenarios.

Scenario	No. projects developed	Impact Years				
		1987	1988	1989	1990	1991
Low incremental	4	0.2	1.8	1.8	1.9	1.9
Low immediate	4	1.9	1.9	1.9	1.9	1.9
Moderate incremental	10	1.8	1.9	2.1	2.3	2.3
Moderate immediate	10	2.3	2.3	2.3	2.3	2.3
Full incremental	20	1.9	2.3	3.5	3.5	3.7
Full Immediate	20	3.7	3.7	3.7	3.7	3.7

1.2 and 1.7 for cold and warm water fishing in Idaho (Sorg et al. 1984). However, consumer surplus was only about 40% of actual expenditures for recreational steelhead fishing in Idaho (Donelly et al. 1983).

Responses to contingent-valuation questions revealed that Swan River anglers consistently attributed a higher value to a hypothetical 25% fish loss than did anglers on Swan Lake or the tributaries (Table 27). Anglers fishing various parts of the drainage reported they would pay from $13 to $76 annually to prevent a 25% loss while they would sell their rights to these fish for $79 to $580 per year. Anglers reported being willing to drive 53 to 127 one-way miles to get to an area equal in quality to the Swan, which amounts to $27 to $64, based on travel costs of $0.25 per mile (Table 27).

Estimates of the total value of a 25% fish loss were derived using creel census estimates of the total number of anglers fishing Swan Lake, River, and tributaries (3733, 2693, and 1405, respectively) as described by ECO Northwest (1984). As displayed in Table 28, the resulting contingent values were substantial, ranging between $250,000 (based on WTD) and $2.6 million (based on WTS) annually. The difference between WTS and the other two contingent-valuation methods (WTP and WTD) is apparently commonplace in the literature.

Variances around contingent-valuation responses were quite large. For example, mean WTP (average response to the WTP question) for the Swan River and tributaries and mean WTS for Swan Lake were not significantly different from zero (Table 27). Willingness-to-drive was found to be the best of the contingent-valuation approaches to discriminate the relative value of the 11 fishing areas surveyed. This may have been because "people can give a clearer response to how many miles they would have to drive rather than how many dollars they would be willing to pay for an environmental amenity" (ECO Northwest 1984).

Hedonic travel-cost analysis resulted in a lower value of a 25% fish loss (Table 28). However, this technique was considered to be more useful in addressing the goals of this study because of its ability to determine the relative value of site characteristics. The results of the hedonic analysis suggested that anglers cared most about target species (especially trout and bull trout), and were less concerned about size of fish and catch rate. Other site characteristics such as type of water (river, lake, reservoir), management designation (trout water, etc.) and scenic qualities did not add significant predictive power to the hedonic models.

The hedonic travel-cost method was used to determine the net economic value of the bull trout fishery in the Swan River drainage. Bull trout were found to be significantly more valuable than "trout" to anglers in the drainage. Anglers were willing to

Table 27. Average responses to contingent valuation questions from anglers in the Swan River drainage. Numbers of responses are in parenthesis. Questions were designed to determine the value of a hypothetical 25% fish loss.

Area	Willingness-to-pay ($/year)	Willingness-to-sell ($/year)	Willingness-to drive (miles/trip)[a/]
Swan Lake	$29* (80)	$241 (82)	89* (173)
Swan River	$76 (111)	$580* (72)	127* (192)
Swan tributaries	$13 (12)	$ 79* (19)	53* (33)

a/ These are one-way miles. Multiply by $0.50 to obtain dollar value.

* Asterisks denote responses significantly different from zero at the 0.05 significance level.

Table 28. Aggregate valuation (dollars per year) of a hypothetical 25% fish loss in the Swan River drainage using four different estimation techniques. Adapted fran ECO Northwest (1984).

Area	Willingness-to-pay	Willingness-to-sell	Willingness-to-drive	Hedonic travel-cost
Swan Lake	$108,300	$ 899,700	$110,800	$ 58,400
Swan River	204,700	1,562,000	114,000	42,100
Swan tributaries	18,300	111,000	24,800	22,000
TOTAL	$331,300	$2,572,700	$249,600	$122,500

pay an estimated $450 per party-visit to fish specifically for bull trout as compared to $30 to fish for "trout". However, there was a large amount of variance associated with these estimates (EC0 Northwest 1984).

Target species information gathered during the creel census indicated that 16% of the Swan Lake and 6% of the Swan River fishing trips were made by bull trout parties, which amounted to 408 and 108 party-visits, respectively. The amount of bull trout fishing in the tributaries could not be estimated because no bull trout anglers were interviewed. Multiplying the estimated bull trout trips by $450 resulted in net values of $183,600 and $48,600 annually for the bull trout fishery in Swan Lake and the Swan River, or $232,200 total. Similar calculations resulted in an estimated net value of $87,000 for non-specific "trout" fishing (including kokanee) in the lake, river, and tributaries.

The hedonic travel-cost results indicated that the bull trout fishery has a substantially greater net value than the trout fishery (including kokanee) in the drainage, even though bull trout comprised a relatively small portion of the harvest and fishing pressure. Consequently, small hydro and forest development impacts on juvenile bull trout populations in the tributary streams could have significant effects on the value of the fishery for this migratory species in downstream areas (Swan River and Swan Lake).

The bioeconomic impacts of small hydro development on the tributary sport fishery would be small due to the distribution of brook trout, which formed the basis of the tributary fishery. Assuming that dewatering constitutes a loss of site and that the total value of the tributary fishery to anglers is due to the presence of brook trout, the travel-cost value estimate was used to determine the net value of brook trout population reductions. Cumulative tributary brook trout losses resulting from dewatering were estimated to range between 2 and 4%. Applying these losses to the travel-cost tributary value estimate ($68,000) indicates an annual loss of $1400 to $2700. This is not to say that cutthroat trout losses (up to 18% at full development) are of no value. This species is important from a genetic standpoint and may at some future time be more avidly sought by tributary anglers. The question of future value was also raised by Gordon et al. (1973).

The results of this economic evaluation indicate that it would be more prudent for small hydro developers to seek streams in the Swan drainage that are not utilized by migratory bull trout. This study and others like it can be used as important planning tools to direct small hydro development, should the need for such power arise. At the present time, the need for such power in the Northwest is questionable. As pointed out by the Northwest Power Planning Council (1983), new power resources must be compatible with the region's existing hydropower system. In other words, new hydropower projects must be able to generate power during the low water period, rather than add to the existing hydropower surplus during the spring high water period. Many of the hydro projects proposed in the Swan drainage would be unable to meet this criterion without causing substantial damage to fisheries resources. Also, it would be very difficult to compare the economic tradeoffs between small hydro development and self-sustaining fisheries resources because small hydro is heavily subsidized by tax incentives and price and market guarantees.

STATUS OF SWAN HYDRO PROJECTS

After the initial flurry of preliminary study permits in 1982, interest in developing the 20 proposed Swan sites began to subside. Many preliminary study permits were surrendered during 1983 after developers realized that the sites had inadequate streamflows, would be very difficult to access, were too far from existing transmission lines, or were otherwise not feasible for development. Preliminary permits were allowed to expire for other projects for various reasons, including the fish and wildlife resource concerns raised by state and federal agencies. Some of these concerns were illuminated by the initial results of this study.

By late 1983, the remaining developer (Hydro Management Inc.) had expressed interest in pursuing licensing for only four sites: Cedar, Cold, Piper, and Squeezer creeks. In March, 1984, new preliminary study permits were issued by FERC for projects on Piper and Squeezer creeks, with no formal action taken on the Cedar and Cold creek projects. Meanwhile, court decisions on regulatory authority for small hydropower and Public Service Commission decisions on "avoided cost" rates began to shape the political and economic boundaries for micro-hydro development. Priority rights for the remaining Swan projects were acquired from Hydro Management by Solar Research Inc. during the first half of 1984.

Discussions held between MDFWP, U.S. Fish and Wildlife Service, USFS, and the developer during the summer and fall of 1984 centered on the minimum instream flow issue and possible mitigation strategies. The developer reiterated that the projects were not economically viable with thesediversion constraints and raised questions about the legitimacy of the method used to derive instream flow recommendations. Offers were made by the developer to undertake stream rehabilitation at offsite locations to compensate for any damage to fish populations caused by project operation. However, the agencies insisted that minimum instream flows were the only acceptable forms of mitigation, especially since bull trout spawning and/or rearing habitats were involvedinthreeofthefour remaining projects. It was further argued that stream improvement techniques were largely unproven for high gradient mountain streams, and that no proven technology existed for creating new rearing habitat for migratory bull trout. The risk of losing these unique fish runs and preferred habitats was considered unacceptable. Since no agreement could be reached on this issue, the developer indicated that he would surrender all remaining study permits.

At this writing, no further interest has been expressed in developing any of the Swan sites. Throughout the review process, the developer complained about receiving conflicting signals from government agencies, including an initial indication that fisheries values were minimal in Swan tributaries. This may have been partly due to a lack of established and coordinated policies for reviewing small hydro proposals by the various resource management agencies involved. The developer also felt that larger projects (e.g. oil and gas pipelines) did not receive the scrutiny applied to his proposals.

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APPENDIX A

Appendix Al. Habitat variables considered in the development of statistical models relating fish abundance to habitat characteristics in tributaries in the Swan River drainage.

Water Quality

- Phosphorus (mg/l)
- Nitrate (mg/l)
- Sulfate (mg/l)
- Sodium (mg/l)
- Potassium (mg/l)
- Calcium (mg/l)
- Magnesium (mg/l)
- Alkalinity (mg/l)
- *Conductivity (mmhos/cm)
- Total dissolved solids (mg/l)
- *Max. summer water temp. (°F)
- Est. late summer flow (cfs)

Reach Characteristics

- Stream order
- *Drainage area (km^2)
- *Reach gradient (%)
- Survey section gradient (%)
- *Survey section elevation (m)
- Upper reach elevation (m)
- Lower reach elevation (m)
- *Channel stability score
- Ave. channel width (m)
- Ave. valley width (m)
- valley : channel ratio
- *Ave. wetted width (m)
- Ave. depth (cm)
- *Max. depth (cm)
- Ave. pool depth (cm)
- *Max. pool depth (cm)

Habitat Characteristics

- Habitat units:
  - Pool (%)
  - Riffle (%)
  - Run (%)
  - Pocket water & cascade (%)
  - *Beaver pond (%)
  - Split channel (%)
  - Side Channel (%)
  - *Split & side channel (%)
  - class I pools (%)
  - class II pools (%)
  - class III pools (%)
- Pools per kilometer:
  - class I
  - class II
  - class I & II
  - Class III
  - *Total
- *Channel debris (%)
- Debris stability (%)
- Overall substrate:
  - Boulder & bedrock (%)
  - Cobble (%)
  - Large gravel (%)
  - Small gravel (%)
  - Sand, silt & detritus (%)
  - *Substrate score
  - D90 (cm)
  - Embeddedness
  - Compaction
- Pool substrate:
  - Boulder & bedrock (%)
  - Cobble (%)
  - Large gravel (%)
  - Small gravel (%)
  - Sand, silt & detritus (%)
  - *Substrate score
  - Embeddedness
- Instream cover:
  - Instream bank cover (%)
  - Aquatic vegetation (%)
  - Logs (%)
  - Debris (%)
  - Logs & debris (%)
  - Boulder (%)
  - Turbulence (%)
  - *Total (%)
  - Overhead cover:
  - Overhead bank cover (%)
  - *Undercut bank (%)
  - *Overhand (%)
  - Understory (%)
  - Overstory (%)
  - Total (%)

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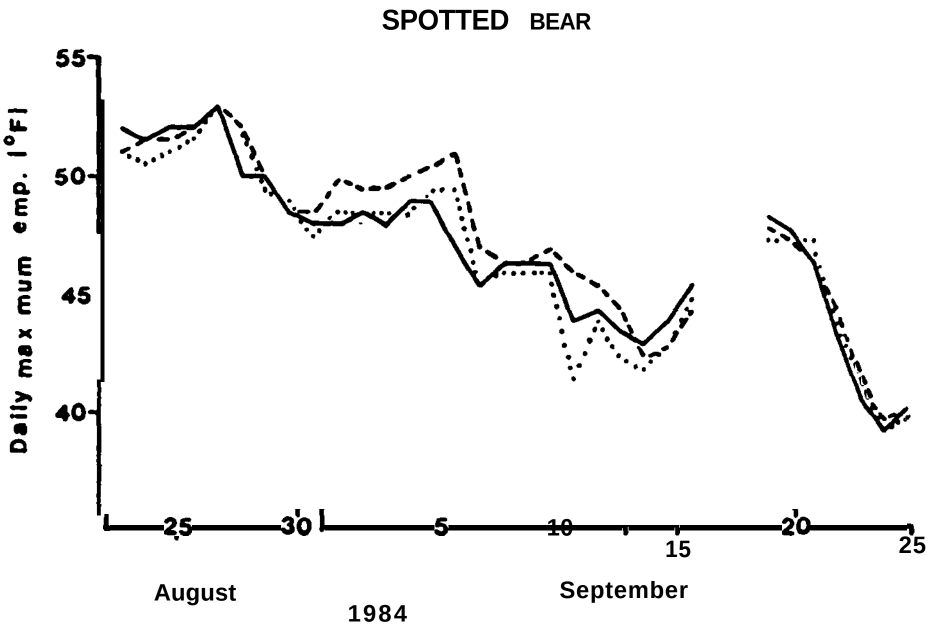
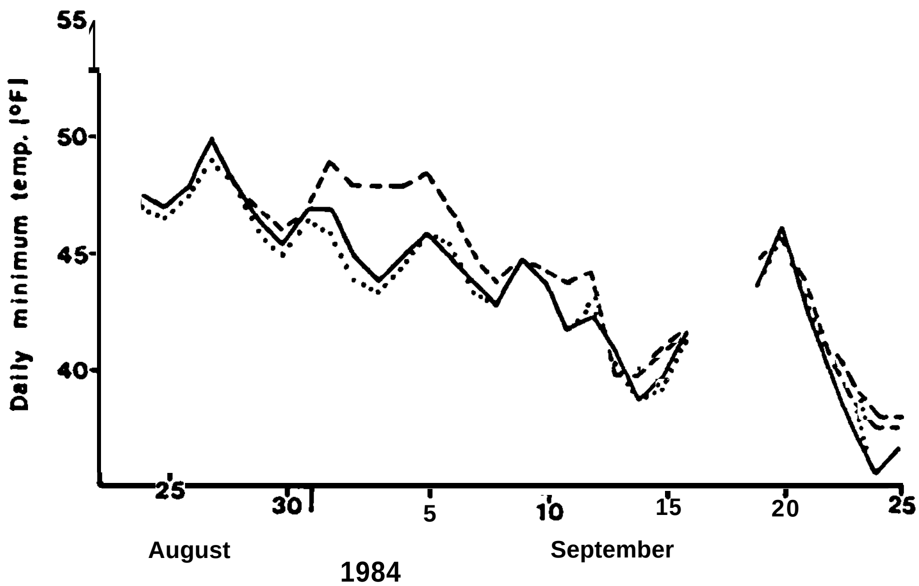
*Selected for possible inclusion in stepwise regression modeling of cutthroat, bull, or brook trout.

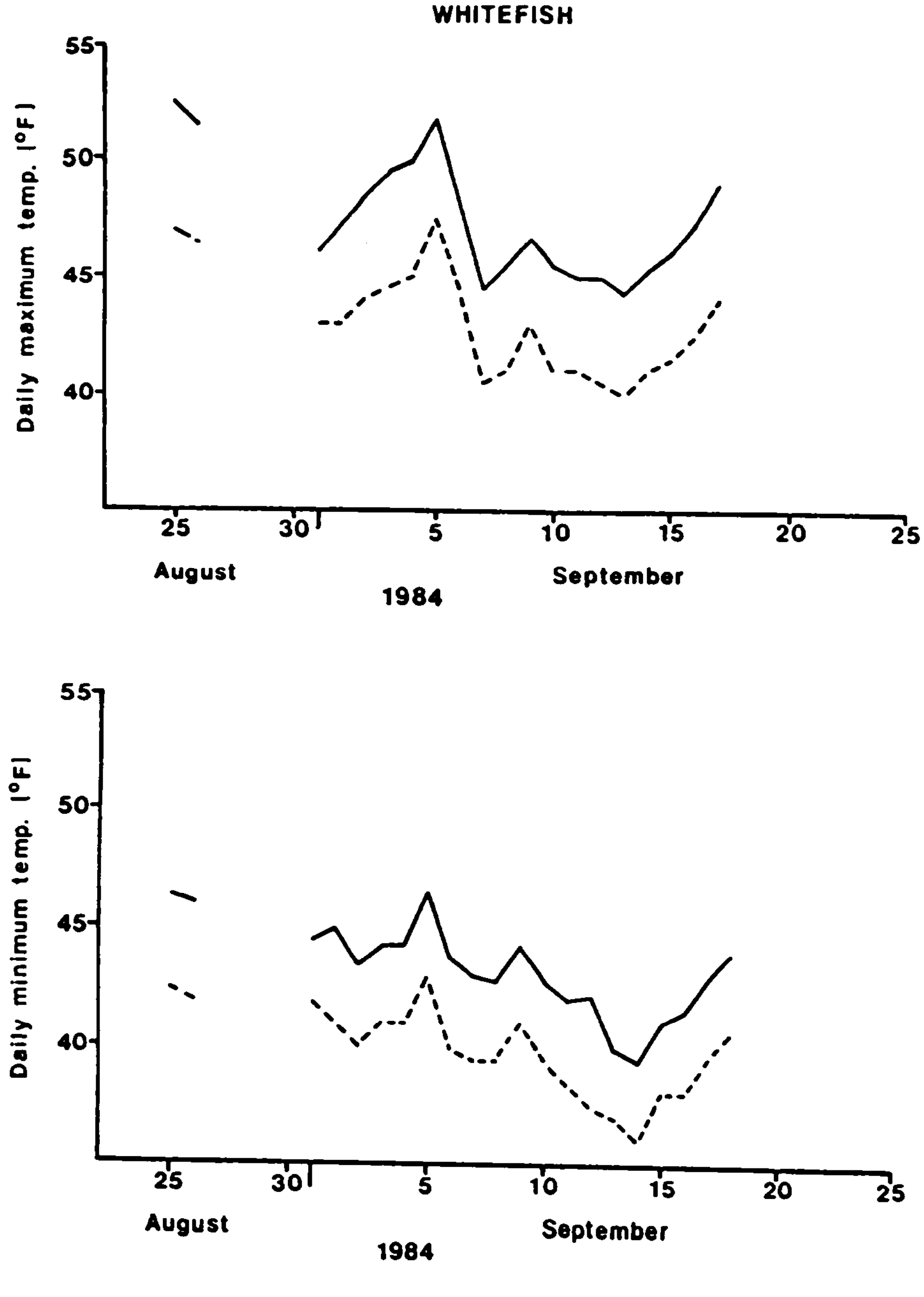
Appendix A2. Bull trout spawning survey coverage in the Swan River drainage during the years 1982-1984. Survey sections are identified by stream kilometers, measured beginning at the mouth or confluence with a larger stream.

Creek	1982 Loc. of survey section	1982 Total km surveyed	1983 Loc. of survey section	1983 Total km surveyed	1984 Loc. of survey section	1984 Total km surveyed
Beaver	km 17.0-0	17.0			—	—
Bond	km 3.8-o	3.8	—	—	—	—
Cedar	km 10.0-0	10.0			—	—
Cilly	km 2.7-.5	2.2	—	—	—	—
Cold	km 17.0-0	17.0	km 14.5-O	14.5	km 14.5-O	14.5
S.Fk Cold	km 7.0-0	7.0	—	—	—	—
Cooney	km 4.5-O	4.5			—	—
Dog	km 7.0-0	7.0	—	—	—	—
Elk	km 16.0-0	16.0	km 16.2-6.7	9.5	km 16.2-6.7	9.5
Glacier	km 22.5-o	22.5	km 20.6-0	20.6	—	—
Goat	km 11.7-O	11.7	km 11.5-O	11.5	km 9.3-o	9.3
Groom	km 2.0-0	2.0	—	—	—	
Hall	km 2.0-0	2.0	—	—	—	—
Jim	—	—	km 4.7-1.4	3.3	km 7.0-1.8	5.2
N.Trib Jim	—	—	km 2.5-0.6	1.9	—	—
Lion	km 11.0-0	11.0	km 10.5-o	10.5	km 10.5-0	10.5
Lost	km 2.3-O	2.3	km 2.3-O	2.3	km 2.3-1.6	0.7
N.Fk Lost	km 11.0-0	11.0	km 8.0-0	8.0	km 5.9-o	5.9
S.Fk Lost	km 10.0-0	10.0	km 10.0-0	10.0	km 7.4-o	7.4
Piper	km 6.0-0	6.0	km 1.7-0.8	.9	km 6.2-O	6.2
Pony	km 6.8-O	6.8	—	—	—	—
Rumble	km 4.3-O	4.3	—	—	—	—
Soup	km 9.5-o	9.5	—	—	—	—
Squeezer	km 12.0-0	12.0	km 7.8-0	7.8	km 6.7-O	6.7
Woodward	km 5.5-O	5.5	km 3.5-o	3.5	—	—
S. Woodward	km 10.0-.2	9.8	km 0.4-0	0.4	—	—
Totals		210.9		104.7		75.9





Appendix A3. Daily maximum (upper graph) and minimum (lower graph) water temperatures during August and September of 1984 at the Addition Creek hydro project located near Spotted Bear on the South Fork of the Flathead River, Montana. Solid lines are temperatures above the diversion, dashed lines are diverted waters immediately below the powerhouse, and dotted lines are creek waters just above the diversion return.



Appendix A4. Daily maximum (upper graph) and minimum (lower graph) water temperatures during August and September of 1984 at the small hydro project on the water supply system for the City of Whitefish, Montana. Solid lines represent the average maximum (or minimum) water temperatures at the two diversion points on a given day. Dashed lines indicate daily maximum (or minimum) temperature of the diverted waters immediately below the powerhouse.

Appendix A5. Continqent-valuation questions used in the economic survey of Swan drainage anglers during the 1983-84 fishing season. All party leaders were asked the WTD question and either the WTP or WTS question.

Technique	Question
Willingness-to-pay (WTP)	Assume that the fish population of the Swan River drainage might permanently decrease by 25 percent. If the only way to prevent this decrease was for fishermen to donate into a special fund to be used exclusively for this purpose, how much money would you be willing to pay into this fund each year?
Willingness-to-sell (WTS)	Assume that the fish population of the Swan River drainage permanently decreased by 25 percent. If a special fund was created to be used exclusively to compensate fishermen for this loss in fishery, how much money from this fund would you have to be paid each year?
willingness-to-drive (WTD)	If the fish population in the swan drainage decreased by 25 percent, how many more miles one way would you be willing to drive to get to a site whose quality is as good as the Swan's before the quality decreased?

APPENDIX B

U. S. DEPARTMENT OF AGRICULTURE

FLATHEAD NATIONAL FOREST

COMPUTER PROGRAM USER INSTRUCTIONS

OCTOBER 1984

I. IDENTIFICATION

PROGRAM NAME: SEDIMENT MODEL
LANGUAGE: Fortran 77
HOST COMPUTER: Data General MV/8000 11
PROGRAMMER: Pat Gilmore
(406) 755-5401

II. PURPOSE

This program computes theoretical annual sediment load8 delivered to stream reaches according to landtype, road building and logging activity in the corresponding subdrainages. The user selects a year of interest and may set an age limit for timber cutting units and/or local road8 to be considered. Also, if desired, a percent of the upstream yield and/or sediment from proposed microhydro projects will be added in.

III. INPUT

First, gather field data. Divide streams into reaches and identify all landtypes in the subdrainage for each reaah. Landtype may be further divided by ownership if desired. Then, note existing and proposed timber cutting units and roads within each ground unit. Last, for each reach, determine gradient, tributaries, and the percent of upstream sediment which enter8 the reach.

Record this data on Form 1 a8 illustrated in the example. Begin by entering the stream name, reach number, landtype code, and ownership code, if used, to identify a unit of groung. Then, list unit acres, logging information, road information, and reach information vertically. When several lines are used for logging, road, and/or reach information, enter the stream, reach, landtype, and ownership on each line. A description of each data field follows.

STREAM NAME - Enter a stream name of up to ten characters. THIS FIELD IS REQUIRED ON EACH LINE!

REACH - Number reaches sequentially upstream. Identify a headwater basin (portion of a drainage basin entering alpine lake) by adding the digit zero to the uppermost reach number. For example, if the highest reach number is 2, its headwater basin should be 20. THIS FIELD IS REQUIRED ON EACH LINE!

LANDTYPE - Valid entries are 1 through 23 as defined below. See attached tables for descriptions. THIS FIELD IS REQUIRED ON EACH LINE!

1 - 10-2, I
2 - 10-3
3 - 12, Ia
4 - 14-2
5 - 14-3
6 - 16
7 - 17
8 - 21-8, 21-9, II
9 - 23-7, 23-8, 26A-7, 26A-8, 26C-7, 26C-8, III(1)
10 - 26D-7, 26D-8, III(2)
11 - 26G-7, 26G-8
12 - 23-9, 26A-9, 26C-9, 26D-9
13 - 27-7, 27-8
14 - 28-7
15 - 32, IV
16 - 57-8, Va(1), Vb(1)
17 - 57-9, Va(2), Vb(2)
18 - 54, 55
19 - 72, 75, VI
20 - 73, VII
21 - 74
22 - 76, 78, VIII
23 - 77

OWNERSHIP - Enter one of the following codes or define your own. This field is optional, but is REQUIRED ON EVERY LINE IF USED!

1 - National Forest lands: non-wilderness
2 - National Forest lands: wilderness
3 - Plum Creek Timber lands (BN)
4 - State of Montana lands (Swan River State Forest)
5 - Other privately owned lands

ACRES - Enter total acres of ground unit in the landtype to the nearest whole number.

ACRES CUT - Enter total acres in cutting unit to the nearest whole number.

YEAR CUT - Enter last two digits of the year the unit was cut.

ROAD TYPE (Constructed or Reconstructed) - Enter one of the codes below.

- L - Local road
- 1 - Collector road, yearly maintenance
- 2 - Colleator road, 2-year maintenance
- 3 - Collector road, 3-year maintenance
- 4 - Colleator road, 4-or-more-year maintenance

MILES (Construated or Reconstructed) - Enter miles of road to the nearest tenth. The last digit entered will be interpreted as tenths, so an entry of 45 will mean 4.5 miles. Reconstructed miles must be no longer than miles constructed.

YEAR (Constructed or Reconstructed) - Enter the last two digits of the year of road construction or reconstruction.

REACH GRADIENT - Enter the reach gradient to the nearest tenth. The last digit will be interpreted as tenths. THIS VALUE MUST BE ENTERED ON THE FIRST DATA LINE FOR THE REACH!

PERCENT UPSTREAM SEDIMENT - Enter the percent of upstream sediment which has been estimated to flow into the reach. THIS VALUE MUST BE ENTERED ON THE FIRST DATA LINE FOR THE REACH!

TRIBUTARY NAMES - Enter tributary names Of up to ten characters. Be sure the spelling is identical to the spelling under stream name.

Form 2 is optional. Use it to record predicted sediment loads to stream reaches by year from proposed microhydro projects. Several alternatives for time of construction can be coded. Reaches may be listed more than once for each alternative 88 shown in the example. Each data field is described below.

YEARS OF INTEREST - Enter the last two digits for up to seven years of interest. The first relevant year of interest for microhydro projects is one year after construction.

PROJECT - Enter the project name or whatever you like. This field is ignored by the oomputer.

STREAM NAME - Enter a stream name of up to ten characters. Be sure the spelling is identical to the spelling onForm 1. THIS FIELD IS REQUIRED ON EACH LINE!

REACH - Enter reach numbers exactly as they were entered on Form 1. THIS FIELD IS REQUIRED ON EACH LINE!

SEDIMENT - Enter tons of sediment to the nearest hundredth that will enter the reach in the year given. The last two digits will be interpreted a8 hundredths, so an entry of 550 will mean 5.50 tons.

Second, create computer files. Column numbers for data entry are given on the forms below the headings for each field. Enter the coefficients from the attaahed tables in one file and the data gathered on Form 1 in a second file. If Form 2 la used, create a separate file for each scenario of **microhydro project construction** RIGHT JUSTIFY ALL NUMERIC ENTRIES AND BE SURE THE DATA FROM FORM 1 IS IN ORDER BY STREAM AND REACH! Your own coeffieients may be substituted for those attached, but the format of thefile must be exactly as described.

IV. OPERATION

Type the command below to execute the program.

X SEDMOD

When prompted, enter the name8 of your files and the program parameters: year of interest, maximum age **of** local roads and cutting units, and whether to add in upstream sediment.

V. OUTPUT

Sample output is attached. Each stream and reach in the data file is listed. Natural sediment is computed by accumulating the products of each landtype acreage in the subdrainage and the natural sediment coefficent for that landtype. Logging sediment is computed similarly except that only acres in cutting units of the proper age are considered and logging sediment coefficients are used. Likewise with road sediment except that road coefficients are multiplied by miles of road and all collector roads are included regardless of age. Also, when microhydro project data is given, it is added to road sediment and does not appear as a separate item on the report. Percent fines, substrate score, and bull trout per 100 square meters are computed as follows:

$$\text{Percent Fines} = 34.18 + \frac{55(\text{Road Sediment})}{(\text{Natural Sediment})} - 24.8(\log_{10} \text{Gradient})$$

$$\text{Substrate Score} = 10.81 - \frac{6(\text{Road Sediment})}{(\text{Natural Sediment})} + 2.91(\log_{10} \text{Gradient})$$

$$\text{Bull Trout Per 100 square meters} = 10^{x}$$

where $x = 0.142(\text{Substrate Score}) - 1.391$.

LANDTYPE DESCRIPTIONS

10-2	Alluvial Lands, well drained
10-3	Alluvial Lands, poorly drained
12	Organic Soils, poorly drained
14-2	Silty Lacustrine, well drained
14-3	Silty Lacustrinc, poorly drained
16	Alluvial Fans, 5 - 30 percent Slopes
17	Avalanche Pans, 20 - 50 percent slopes
21-8	Alpine Glacial Till-Residual Soils, 20 - 40 percent slopes
21-9	Alpine Glacial Till-Residual Soils, 40 - 60 percent slopes
23-7	Silty Glacial Till-Residual Soils, 0 - 20 percent slopes
23-8	Silty Glacial Till-Residual Soils, 20 - 40 percent slopes
23-9	Silty Glacial Till-Residual Soils, 40 - 60 percent slopes
24-8	Sandy Glacial Till-Residual Soils, 20 - 40 percent slopes
24-9	Sandy Glacial Till-Residual Soils, 40 - 60 percent slopes
26A-7	Silty Glacial Till, calcareous substratum, 0 - 20 percent slopes
26A-8	Silty Glacial Till, calcareous substratum, 20 - 40 percent slopes
26A-9	Silty Glacial Till, calcareous sbustratum, 40 - 60 percent slopes
26C-7	Silty Glacial Till, slightly acid substratum, 0 - 20 percent slopes
26C-8	Silty Glacial Till, slightly acid substratum, 20 - 40 percent slopes
26C-9	Silty Glacial Till, slightly acid substratum, 40 - 60 percent slopes
26D-7	Sandy Glacial Till, 0 - 20 percent slopes
26D-8	Sandy Glacial Till, 20 - 40 percent slopes
26D-9	Sandy Glacial Till, 40 - 60 percent slopes
26C-7	Silty Glacial Till, calcareous substratum, warm and dry, 0 - 20 percent slopes
26G-8	Silty Glacial Till, calcareous substratum, warm and dry, 20 - 40 percent slopes
26I-7	Clayey Glacial Till, 0 - 20 percent slopes
26I-8	Clayey Glacial Till, 20 - 40 percent slopes
26J-7	Loamy Glacial Till, 0 - 20 percent slopes
26J-8	Loamy Glacial Till, 20 - 40 percent slopes
26J-9	Loamy Glacial Till, 40 - 60 percent slopes
26L-7	Clayey Glacial Till. "old surface," 0 - 20 percent slopes
26L-8	Clayey Glacial Till, "old surface," 20 - 40 percent slopes
27-7	Loamy Glacial Drift, 0 - 20 percent slopes
27-8	Loamy Glacial Drift, 20 - 40 percent slopes
28-7	Glacial Outwash, 0 - 20 percent slopes
31	Mass Failure Lands, hummocky, 10 and 30 percent slopes
32	Mass Failure Lands, benchy, 30 and 50 percent slopes
54	Slab Rock, high elevation - 10 - 30 percent slopes
55	Slab Rock, steep - 30 - 60 percent slopes
57-8	Residual Soils, 20 - 40 percent slopes
57-9	Residual Soils, 40 - 60 percent slopes
72	Glacial Breaklands, cirque headwall and alpine ridge 60 percent plus slopes
73	Glacial Breaklands, troughwall, 60 percent plus slopes
74	Fluvial Breaklands, 60 percent plus slopes
75	Structural Breaklands, scarp rock, 60 percent plus slopes
76	Structural Breaklands, weak dissection, 60 percent plus slopes
77	Structural Breaklands, moderate dissection, 60 percent plus slopes
78	Structural and Glacial Breaklands, warm and dry, 60 percent plus slopes

LAND TYPE ASSOCIATIONS (WILDERNESS)

Symbol	Name of Happing Unit
I	Forested Floodplains
Ia	Wet, Crass-sedge Meadows
Ib	Grass 6 Forested Stream Terraces
11	Glacial Cirque Basins
III (1)	Forested Ground Moraine, silty
III (2)	Forested Ground Moraine, sandy
IIIa	Forested Steep lateral Moraine
IV	Slump Land
Va (1)	Forested High Elevation Ridges, 20-40% Slopes
Va (2)	Forested High Elevation Ridges, 40-60% Slopes
Vb (1)	Forested Smooth Residual Slopes, 20-40% Slopes
Vb (2)	Forested Smooth Residual Slopes, 40-60% Slopes
vc	Forested Moderately Dissected Residual Slopes
Vd	Forested and Grassland Moderately Dissected Residual Slopes
Ve	Forested & Grassland Smooth Residual Slopes
VI	Peaks and Alpine Ridges - Sparsely Vegetated Rockland
VII	Forested, Cool Aspect Breaklands
VIII	Forested, Warm Aspect Breaklands

LANDTYPE SEDIMENT COEFFICIENTS FOR ESTIMATING NATURAL AND MAN-INDUCED SEDIMENT LOADS TONS/YEAR DELIVERED TO STREAM CHANNELS

Landtype	Natural Sediment (tons/ac/yr)	Road Construction Sediment[1] (tons/mi/yr)				Road Maintenance Sediment[2] (tons/mi/yr)			Skid Trail Sediment[3] (tons/mi/yr)				Landing Sediment[4] (tons/ac/yr)				Fireline Sediment[5] (tons/1000'/yr) Tractor		Hand	
		Yr.1	Yr.2	Yr.3-4	Yr.5+	Yr.1	Yr.2	Yr.3+	Yr.1	Yr.2	Yr.3	Yr.4-10	Yr.1	Yr.2	Yr.3	Yr.4-10	Yr.1	Yr.2	Yr.1	Yr.2
1	0.85	0.95	0.57	0.29	0.15	0.57	0.29	0.15	0.19	0.19	0.10	0.06	0.19	0.11	0.06	0.03	0.04	0.02	0.02	0.01
2	0.84	1.50	0.90	0.46	0.23	0.90	0.46	0.23	0.30	0.30	0.15	0.09	0.46	0.28	0.14	0.07	0.06	0.03	0.03	0.01
3	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.07	23.77	14.26	7.13	3.57	14.26	7.13	3.57	4.75	4.75	2.38	1.36	6.53	3.92	1.96	0.98	0.90	0.45	0.45	0.22
5	0.15	1.42	0.85	0.43	0.22	0.85	0.43	0.22	0.28	0.28	0.14	0.08	0.65	0.39	0.20	0.10	0.01	0	0	0
6	0.15	0.95	0.57	0.29	0.15	0.57	0.29	0.15	0.19	0.19	0.10	0.06	0.38	0.23	0.12	0.06	0.04	0.02	0.02	0.01
7	0.16	3.08	1.84	0.91	0.46	1.84	0.91	0.46	0.62	0.62	0.31	0.18	0.44	0.26	0.13	0.07	0.12	0.06	0.06	0.03
8	0.18	33.80	20.28	10.14	5.07	20.28	10.14	5.07	6.76	6.76	3.38	1.93	6.97	4.18	2.09	1.05	1.28	0.64	0.64	0.32
9	0.07	35.67	21.40	10.70	5.35	21.40	10.70	5.35	7.13	7.13	3.57	2.04	9.80	5.88	2.94	1.47	1.35	0.67	0.67	0.34
10	0.07	21.17	12.70	6.35	3.18	12.70	6.35	3.18	4.23	4.23	2.12	1.21	5.88	3.53	1.76	0.88	0.80	0.40	0.40	0.20
11	0.08	23.51	14.10	7.05	3.53	14.10	7.05	3.53	4.70	4.70	2.35	1.35	6.53	3.92	1.96	0.98	0.89	0.44	0.44	0.22
12	0.18	47.53	28.52	14.26	7.13	28.52	14.26	7.13	9.51	9.51	4.76	2.72	9.80	5.88	2.94	1.47	1.80	0.90	0.90	0.45
13	0.15	2.18	1.31	0.65	0.33	1.31	0.65	0.33	0.44	0.44	0.22	0.13	0.87	0.52	0.26	0.13	0.08	0.04	0.04	0.02
14	0.15	1.90	1.14	0.58	0.29	1.14	0.58	0.29	0.38	0.38	0.19	0.11	0.76	0.46	0.23	0.12	0.07	0.04	0.04	0.02
15	0.10	26.15	15.69	7.85	3.93	15.69	7.85	3.93	5.23	5.23	2.62	1.50	5.23	3.14	1.57	0.79	0.99	0.49	0.49	0.25
16	0.10	2.39	1.43	0.72	0.36	1.43	0.72	0.36	0.48	0.48	0.24	0.14	0.76	0.46	0.23	0.12	0.09	0.05	0.05	0.02
17	0.10	3.13	1.88	0.94	0.47	1.88	0.94	0.47	0.63	0.63	0.32	0.18	0.76	0.46	0.23	0.12	0.12	0.06	0.06	0.03
18	0	0.74	0.44	0.22	0.11	0.44	0.22	0.11	0.15	0.15	0.08	0.05	0.18	0.11	0.06	0.03	0.03	0.01	0.01	0.01
19	0.04	0.74	0.44	0.22	0.11	0.44	0.22	0.11	0.15	0.15	0.08	0.05	0.18	0.11	0.06	0.03	0.03	0.01	0.01	0.01
20	1.85	97.87	58.72	29.36	14.68	58.72	29.36	14.68	19.57	19.57	9.79	5.60	16.15	9.69	4.85	2.43	3.70	1.85	1.85	0.93
21	34.76	272.85	163.71	81.86	40.93	163.71	81.86	40.93	54.57	54.57	27.29	15.59	54.74	32.84	16.42	8.21	10.31	5.16	5.16	2.59
22	0.21	31.85	19.11	9.56	4.78	19.11	9.56	4.78	6.37	6.37	3.19	1.82	4.55	2.73	1.38	0.69	1.20	0.60	0.60	0.30
23	0.19	42.49	25.49	12.75	6.37	25.49	12.75	6.37	8.50	8.50	4.25	2.43	6.07	3.64	1.82	0.91	1.61	0.80	0.80	0.40

[1] Acres of ground bared per mile of road times tons of sediment per acre of bare ground. Second year sediment is 60% of first year sediment. Third and fourth year sediment are each 30% of the first year. Fifth year and after are 15% of first year sediment for each year.

[2] Acres of ground rebared by road surface blading and ditch cleaning per mile of road times 60% of a newly built road sediment load. Second year is 50% of first year road maintenance. Third year and after are 25% of first year road maintenance sediment.

[3] Acres of ground bared is considered to be one-fifth as much as for road building. Second year skid trail sediment is the same as first year. Third year sediment is 50% of first year sediment. Fourth through tenth years are about 30% of first year sediment for each year.

[4] One acre of landing site equals one acre of bare ground. Second year sediment is 60% of first year sediment. Third year is 30% of first year. Fourth through tenth years are 15% of first year sediment for each year.

[5] Firelines are assumed to be bare ground. Tractor lines are considered to be one-fifth the width of a road, hand lines one-tenth. Second year fireline sediment is 50% of first year sediment.

NATURAL SEDIMENT COEFFICIENTS
TONS/ACRE/YEAR DELIVERED TO STREAM CHANNELS

LAND TYPE	COEFFI-CIENT	LAND TYPE	COEFFI-CIENT	LAND TYPE	COEFFI-CIENT	LAND TYPE	COEFFI-CIENT
1	.85	7	.16	13	.15	19	.04
2	.84	8	.18	14	.15	20	1.85
3	.13	9	.07	15	.10	21	34.76
4	.07	10	.07	16	.10	22	.21
5	.15	11	.08	17	.10	23	.19
6	.15	12	.18	18	0		

(Enter on lines 24-46 in columns 1-6. Omit decimals. Two places are assumed.)

ROAD SEDIMENT COEFFICIENTS
TONS/MILE/YEAR DELIVERED TO STREAM CHANNELS

	LOCAL ROADS					COLLECTOR ROADS				
AGE	1	2	3-4	5-10	>10	1	2	3	4+	MTC
COLUMNS	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	COLUMNS
L 1	.95	.57	.29	.15	.21	.57	.43	.34	.29	1 L
A 2	1.50	.90	.46	.23	.32	.92	.69	.54	.46	2 A
N 3	0	0	0	0	0	0	0	0	0	3 N
D 4	23.77	14.26	7.13	3.57	5.00	14.26	10.70	8.32	7.13	4 D
T 5	1.42	.85	.43	.22	.30	.85	.64	.50	.43	5 T
Y 6	.95	.57	.29	.15	.21	.58	.44	.34	.29	6 Y
P 7	3.08	1.84	.91	.46	.64	1.82	1.36	1.06	.91	7 P
E 8	33.80	20.28	10.14	5.07	7.10	20.28	15.21	11.83	10.14	8 E
9	35.67	21.40	10.70	5.35	7.50	21.40	16.05	12.48	10.70	9
10	21.17	12.70	6.35	3.18	4.45	12.70	9.52	7.41	6.35	10
11	23.51	14.10	7.05	3.53	4.94	14.11	10.58	8.23	7.06	11
12	47.53	28.52	14.26	7.13	9.98	28.52	21.39	16.64	14.26	12
13	2.18	1.31	.65	.33	.46	1.30	.98	.76	.65	13
14	1.90	1.14	.58	.29	.41	1.15	.86	.67	.58	14
15	26.15	15.69	7.85	3.93	5.50	15.70	11.78	9.16	7.85	15
16	2.39	1.43	.72	.36	.50	1.43	1.08	.84	.72	16
17	3.13	1.88	.94	.47	.66	1.88	1.41	1.10	.94	17
18	.74	.44	.22	.11	.15	.44	.33	.26	.22	18
19	.74	.44	.22	.11	.15	.44	.33	.26	.22	19
20	97.87	58.72	29.36	14.68	20.55	58.72	44.04	34.25	29.36	20
21	272.85	163.71	81.86	40.93	57.30	163.71	122.78	95.50	81.86	21
22	31.85	19.11	9.56	4.78	6.69	19.11	14.34	11.15	9.56	22
23	42.49	25.49	12.75	6.37	8.92	25.49	19.12	14.87	12.75	23

(Enter on lines 24-46. Omit decimals. Two places are assumed.)

LOGGING SEDIMENT COEFFICIENTS
TONS/ACRE/YEAR DELIVERED TO STREAM CHANNELS
(Dash indicates data does not exist)

AGE	1			2			3			4-10			AGE
ACRES	1-5	6-20	>20	1-5	6-20	>20	1-5	6-20	>20	1-5	6-20	>20	ACRES
COLUMNS	1 6	7 12	13 18	19 24	25 30	31 36	37 42	43 48	49 54	55 60	61 66	67 72	COLUMNS
L 1	.07	.03	-	.05	.02	-	.02	1	-	.02	1	-	1 L
A 2	0	1	-	0	0	-	0	0	-	0	0	-	2 A
N 3	-	-	-	-	-	-	-	-	-	-	-	-	3 N
D 4	2.08	1.01	.57	1.43	.66	.42	.72	.29	.20	.38	.15	.11	4 D
T 5	.16	.07	.03	.10	.04	.02	.05	.02	.01	.02	.01	.01	5 T
Y 6	.10	.05	.02	.06	.03	.02	.04	.01	.01	.02	.01	0	6 Y
P 7	-	-	-	-	-	-	-	-	-	-	-	-	7 P
E 8	2.38	1.21	-	1.69	.80	-	.84	.34	-	.44	.18	-	8 E
9	3.13	1.52	.86	2.15	.99	.63	1.08	.43	.30	.56	.22	.16	9
10	1.87	.91	.52	1.28	.59	.38	.64	.26	.18	.34	.13	.10	10
11	2.08	1.01	.57	1.42	.66	.42	.72	.28	.20	.38	.15	.11	11
12	0	.18	.05	0	.09	.02	0	0	0	0	0	0	12
13	.24	.11	.11	.14	.07	.03	.07	.03	.02	.04	.02	.01	13
14	.20	.10	.05	.12	.06	.03	.06	.02	.01	.04	.01	.01	14
15	.50	.40	-	.50	.30	-	.25	.10	-	.14	.06	-	15
16	.24	.11	.06	.16	.07	.05	.08	.03	.02	.04	.02	.01	16
17	0	.01	0	0	.01	0	0	0	0	0	0	0	17
18	-	-	-	-	-	-	-	-	-	-	-	-	18
19	-	-	-	-	-	-	-	-	-	-	-	-	19
20	0	.37	.09	0	.18	.05	0	0	0	0	0	0	20
21	-	-	-	-	-	-	-	-	-	-	-	-	21
22	0	.21	.08	0	.11	.04	0	0	0	0	0	0	22
23	0	.28	.10	0	.14	.05	0	0	0	0	0	0	23

(These coefficients were used before the skidtrail coefficients on the next page were developed. Enter the set you prefer on lines 1-23. Omit decimals. Two places are assumed. Use -1 for dash.)

SKIDTRAIL SEDIMENT COEFFICIENTS
TONS/ACRE/YEAR DELIVERED TO STREAM CHANNELS
(Dash indicates data does not exist)

AGE		1			2			3			4-10			AGE	
ACRES		1-5	6-20	>20	1-5	6-20	>20	1-5	6-20	>20	1-5	6-20	>20	ACRES	
COLUMNS		1 6	7 12	13 18	19 24	25 30	31 36	37 42	43 48	49 54	55 60	61 66	67 72	COLUMNS	
L	1	.02	.01	-	.02	.01	-	.01	0	-	.01	0	-	1	L
A	2	0	0	-	0	0	-	0	0	-	0	0	-	2	A
N	3	-	-	-	-	-	-	-	-	-	-	-	-	3	N
D	4	.45	.18	.20	.45	.18	.20	.22	.09	.10	.13	.05	.06	4	D
T	5	0	0	0	0	0	0	0	0	0	0	0	0	5	T
Y	6	.01	0	0	.01	0	0	.01	0	0	0	0	0	6	Y
P	7	-	-	-	-	-	-	-	-	-	-	-	-	7	P
E	8	.64	.26	-	.64	.26	-	.32	.13	-	.18	.07	-	8	E
	9	.68	.27	.30	.68	.27	.30	.34	.14	.15	.20	.08	.09	9	
	10	.40	.16	.18	.40	.16	.18	.20	.08	.09	.12	.05	.05	10	
	11	.44	.18	.20	.44	.18	.20	.22	.09	.10	.13	.05	.06	11	
	12	0	0	0	0	0	0	0	0	0	0	0	0	12	
	13	.02	.01	.01	.02	.01	.01	.01	0	0	.01	0	0	13	
	14	.01	.01	.01	.01	.01	.01	.01	0	0	.01	0	0	14	
	15	.50	.20	-	.50	.20	-	.25	.10	-	.14	.06	-	15	
	16	.04	.02	.02	.04	.02	.02	.02	.01	.01	.02	.01	.01	16	
	17	0	0	0	0	0	0	0	0	0	0	0	0	17	
	18	-	-	-	-	-	-	-	-	-	-	-	-	18	
	19	-	-	-	-	-	-	-	-	-	-	-	-	19	
	20	0	0	0	0	0	0	0	0	0	0	0	0	20	
	21	-	-	-	-	-	-	-	-	-	-	-	-	21	
	22	0	0	0	0	0	0	0	0	0	0	0	0	22	
	23	0	0	0	0	0	0	0	0	0	0	0	0	23	

(Enter on lines 1-23. Omit decimals. Two places are assumed. Use -1 for dash.)

S E D I M E N T   M O D E L   D A T A   F O R M   1

(* 1 DECIMAL PLACE ASSUMED)

GROUND UNIT INFORMATION					LOGGING ACTIVITY		ROADS CONSTRUCTED			ROADS RECONSTRUCTED			REACH INFORMATION		
STREAM NAME 1 10	REACH 12 13	LAND TYPE 15 16	OWN 18	ACRES 20 23	ACRES CUT 25 27	YEAR CUT 29 30	TYP 32	* MILES 34 36	YEAR 38 39	TYP 41	* MILES 43 45	YEAR 47 48	* GRAD 50 52	% UPS SED 54 56	TRIBUTARY NAMES 58 67
ELK	1	9	1	576	40	78	3	8	--	-	---	--	24	57	NE ELK
ELK	1	9	1	----	45	77	4	1	--	-	---	--	---	---	SE ELK
ELK	1	9	1	----	---	--	6	10	70	2	5	81	---	---	----------
ELK	1	9	3	1041	10	82	3	1	--	-	---	--	---	---	----------
ELK	1	9	3	----	25	79	-	---	--	-	---	--	---	---	----------
ELK	1	9	3	----	15	79	-	---	--	-	---	--	---	---	----------
ELK	1	9	3	----	22	79	-	---	--	-	---	--	---	---	----------
ELK	1	9	3	----	12	81	4	14	--	-	---	--	---	---	----------
ELK	1	9	3	----	20	81	6	3	80	-	---	--	---	---	----------
ELK	1	9	3	----	19	80	6	19	70	-	---	--	---	---	----------
ELK	1	9	5	72	---	--	-	---	--	-	---	--	---	---	----------
ELK	1	10	3	48	---	--	-	---	--	-	---	--	---	---	----------
ELK	1	14	3	11	---	--	-	---	--	-	---	--	---	---	----------
ELK	1	20	1	56	---	--	-	---	--	-	---	--	---	---	----------
ELK	1	20	3	78	---	--	-	---	--	-	---	--	---	---	----------
ELK	2	8	1	211	---	--	-	---	--	-	---	--	18	61	NE ELK
ELK	2	8	2	288	---	--	-	---	--	-	---	--	---	---	SE ELK
ELK	2	8	3	76	---	--	-	---	--	-	---	--	---	---	----------
ELK	2	9	1	207	---	--	-	---	--	-	---	--	---	---	----------
ELK	2	9	2	140	---	--	-	---	--	-	---	--	---	---	----------
ELK	2	9	3	239	---	--	-	---	--	-	---	--	---	---	----------
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SEDIMENT MODEL DATA FORM 2

YEARS OF INTEREST (ENTER ON FIRST LINE OF FILE ONLY)	39-40	45-46	51-52	57-58	63-64	69-70	75-76
	87	88	89	90	91	--	--

PROJECT	STREAM NAME	REACH	SEDIMENT (TONS / 2 DECIMAL PLACES ASSUMED)						
1-20	22-31	33-34	36-40	42-46	48-52	54-58	60-64	66-70	72-76
SQUEEZER	SQUEEZER	1	2448	1444	658	658	330		
	SQUEEZER	2	3210	1926	963	963	481		
PIPER	PIPER	1	0	1510	862	321	321		
	PIPER	2	0	9631	5778	2889	2889		
CEDAR	CEDAR	1	0	0	2728	1637	819		
	CEDAR	2	0	0	25425	15255	7628		
	PIPER	1	0	0	142	71	0		
COLD	COLD	3	0	0	0	17634	10544		

S E D I M E N T   M O D E L

YEAR OF INTEREST:	83	DATE RUN:	09/17/84
CUTTING UNIT AGE LIMIT:	6	DATA FILE:	SEDMOD.DATA.NOLASIN
LOCAL ROAD AGE LIMIT:	20	COEFFICIENTS FILE:	SEDMOD.COEF.CRIG
UPSTREAM SEDIMENT INCLUDED?	Y	PROJECTS FILE:	

STREAM	REACH	NATURAL SEDIMENT	LOGGING SEDIMENT	ROAD SEDIMENT	TOTAL SEDIMENT	LOG/NAT SEDIMENT	ROAD/NAT SEDIMENT	LOG+RD/NAT SEDIMENT	PERCENT FINES	SUBSTRATE SCORE	FULL TROUT PER 100SQM
BETHAL	1	2392.00	.00	1.61	2393.61	.00	.00	.00	6.76	14.03	3.97
BOND	1	7417.96	.00	8.56	7426.52	.00	.00	.00	14.77	13.09	2.93
BOND	2	1830.11	.00	.00	1830.11	.00	.00	.00	.00	.00	.00
CEDAR	1	3465.50	4.67	43.35	3513.52	.00	.01	.01	30.50	11.25	1.61
CEDAR	2	759.19	.00	.00	759.19	.00	.00	.00	12.34	13.37	3.22
CLIFF	1	1037.58	.00	31.44	1069.02	.00	.03	.03	.00	.00	.00
COLD	1	1964.73	273.11	217.24	2455.08	.14	.11	.25	64.57	7.25	.43
COLD	2	2768.25	349.75	219.86	3337.86	.13	.08	.21	16.29	12.95	2.80
COLD	3	126.74	.00	.00	126.74	.00	.00	.00	.00	.00	.00
CRAZYHORSE	1	536.17	.00	.00	536.17	.00	.00	.00	.00	.00	.00
CRAZYHORSE	2	438.97	.00	.00	438.97	.00	.00	.00	19.25	12.56	2.47
CRAZYHORSE	3	144.16	.00	.00	144.16	.00	.00	.00	.00	.00	.00
ELK	1	3561.00	79.47	50.10	3690.57	.02	.01	.04	25.52	11.53	1.95
ELK	2	4547.15	.00	.00	4547.15	.00	.00	.00	27.85	11.55	1.76
FATTY	1	2159.35	6.56	63.51	2229.42	.00	.03	.03	.00	.00	.00
GLACIER	1	5576.20	73.02	261.71	5910.93	.01	.05	.06	31.24	11.18	1.57
GLACIER	2	3087.08	.00	157.15	3244.23	.00	.06	.06	.00	.00	.00
GLACIER	3	3933.16	.00	42.01	3975.18	.00	.01	.01	.00	.00	.00
GLACIER	4	346.46	.00	.00	346.46	.00	.00	.00	8.06	13.87	3.79
GOAT	1	7061.09	260.59	277.32	7598.99	.04	.04	.06	31.97	11.09	1.53
GOAT	2	5682.56	460.57	303.35	6446.48	.08	.05	.13	30.79	11.23	1.60
GOAT	3	5777.35	66.56	197.88	6041.79	.01	.03	.05	18.52	12.66	2.55
GOAT	4	3351.36	.00	56.35	3407.71	.00	.01	.01	26.99	11.06	1.64
GOAT	5	948.51	.00	3.21	951.72	.00	.00	.00	.00	.00	.00
GOAT	6	198.75	.00	.00	198.75	.00	.00	.00	.00	.00	.00
GROOM	1	184.41	.00	.18	184.60	.00	.00	.00	9.65	13.69	3.57
GROOM	2	173.48	.00	.00	173.48	.00	.00	.00	1.24	14.08	4.93
GROOM	3	23.96	.00	.00	23.96	.00	.00	.00	.00	.00	.00
HALL	1	1656.79	.00	1.58	1658.37	.00	.00	.00	20.15	12.46	2.39
HALL	2	2079.78	.00	2.38	2082.16	.00	.00	.00	19.31	12.56	2.47
KRAFT	1	2788.35	28.85	120.94	2938.14	.01	.04	.05	.00	.00	.00
KRAFT	2	2116.15	31.67	146.81	2294.63	.01	.07	.08	17.51	12.60	2.67
KRAFT	3	529.41	31.97	43.96	605.34	.06	.08	.14	.00	.00	.00
LION	1	7917.23	5.84	150.66	8073.73	.00	.02	.02	23.39	12.06	2.11
LION	2	6510.65	.00	.00	6510.65	.00	.00	.00	17.74	12.74	2.66
LION	3	1433.15	.00	.00	1433.15	.00	.00	.00	.00	.00	.00
LOST	1	7422.72	.78	220.50	7644.00	.00	.03	.03	36.95	10.50	1.25
NF ELK	1	863.21	.00	.00	863.21	.00	.00	.00	9.02	13.07	3.55
NF ELK	2	737.86	.00	.00	737.86	.00	.00	.00	13.69	13.21	3.06
NF ELK	3	116.70	.00	.00	116.70	.00	.00	.00	.00	.00	.00
NF LOST	1	7203.49	.00	159.52	7363.01	.00	.02	.02	21.02	12.36	2.32
NF LOST	2	3004.10	.00	71.20	3075.31	.00	.02	.02	15.49	13.01	2.86
NF LOST	3	873.43	.00	.00	873.43	.00	.00	.00	.00	.00	.00
PIPER	1	1046.56	55.13	56.06	1157.75	.05	.05	.11	27.70	11.59	1.80
PIPER	2	1549.17	86.13	67.41	1702.71	.06	.04	.10	18.22	12.53	2.53
PIPER	3	212.71	.00	.00	212.71	.00	.00	.00	.00	.00	.00